DEC 8 1910

JOURNAL OF ELECTRICITY

POWER AND GAS

Devoted to the Conversion, Transmission and Distribution of Energy

Entered as second class matter May 7, 1906, at the Post Office at San Francisco, Cal., under the Act of Congress March 3, 1879

VOL. XXV No. 23 | SAN FRANCISCO, DECEMBER 3, 1910 | PER COPY, 10 CENTS

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JOURNAL OF ELECTRICITY
POWER AND GAS
Devoted to the Conversion, Transmission and Distribution of Energy

VOLUME XXV SAN FRANCISCO, DECEMBER 3, 1910. NUMBER 23

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FRICTION OF FLAT DISCS ROTATED IN WATER

BY JOSEPH N. LE CONTE.[1]

The object of the series of tests herein described was to determine the effect of diameter and speed upon the power necessary to rotate flat circular discs in water, and also the effect of the width of space between the moving plate and the stationary walls of the containing vessel. To a certain extent the effect of temperature on power consumption was touched upon, and in one instance the effect of rusting the surface.

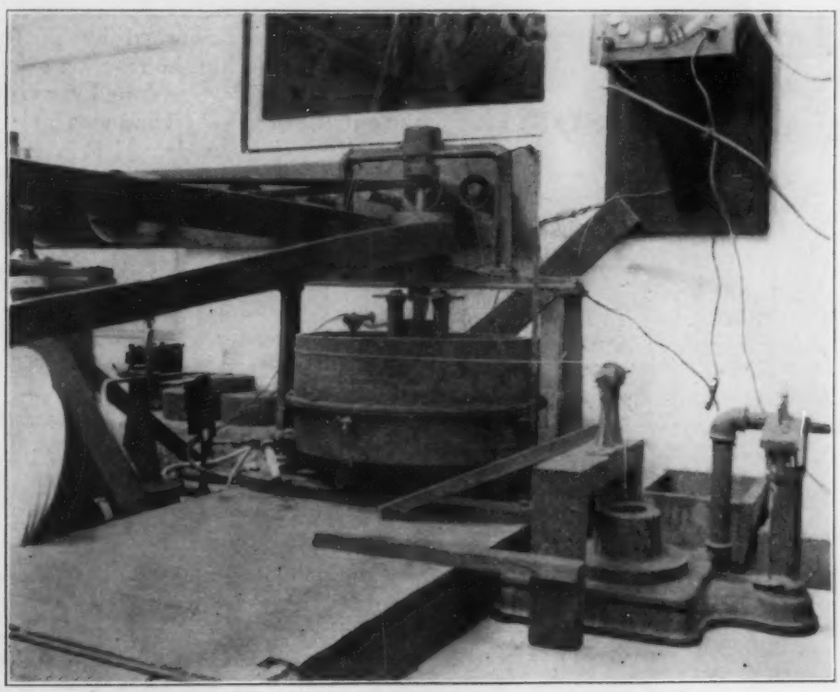

Photo by H. F. Fischer Experimental Apparatus for Determining Friction of Flat Discs Rotated in Water.

Work along similar lines has been done by Prof. Jas. Thomson, as described in the Transactions of the Royal Society, 1855, and by Prof. W. C. Unwin in the Proceedings of the Institution Civil Eng. in 1885. These tests were all made on low speeds, and on a comparatively small scale.

Prof. F. G. Hesse carried on a series of tests similar to and with an apparatus identical with ours, but investigated the power consumption on discs only up to 12 in. diameter, and with comparatively low speeds. He did not publish any information on the effect of the space between fixed and rotating plates upon power consumption, and in his results assumed the power to vary as to the cube of the speed and fifth power of the diameter, making up the difference between theory and actual observations by a variable coefficient.

The tests described in this paper cover the ground more fully than those made by Prof. Hesse, and the apparatus used was larger, and the speed control better than he was able to use. It was not possible, however, to investigate fully many interesting features, particularly those connected with temperature, and with end thrust due to unsymmetrical spacing.

Description of Apparatus.

Fig. 1 shows the general arrangement of the testing apparatus. It consisted of a hollow cylindrical cast

[1]Professor of Mechanical Engineering, University of California.

iron shell M N. divided across the middle horizontal plane at oo'. This shell was finished inside, and the two halves bolted together with a water tight gasket. The shell or container rested upon a hardened steel pivot K, and was held in a vertical position by four rollers R, touching upon the projecting end of a bronze bushing, which also formed the bearing of the rotating shaft. A piano wire suspension S S T passed over a pulley about 20 ft. above the apparatus, and weights on the other end counterbalanced all but about 15 lb. of the weight of the container and its charge of water. The friction at the pivot K was therefore small, and was still further eliminated by the jarring of the frame when the disc was run at high speed.

The disc to be tested was fastened to the lower end of a vertical steel shaft exactly in the axis of the container. End play was prevented by means of the

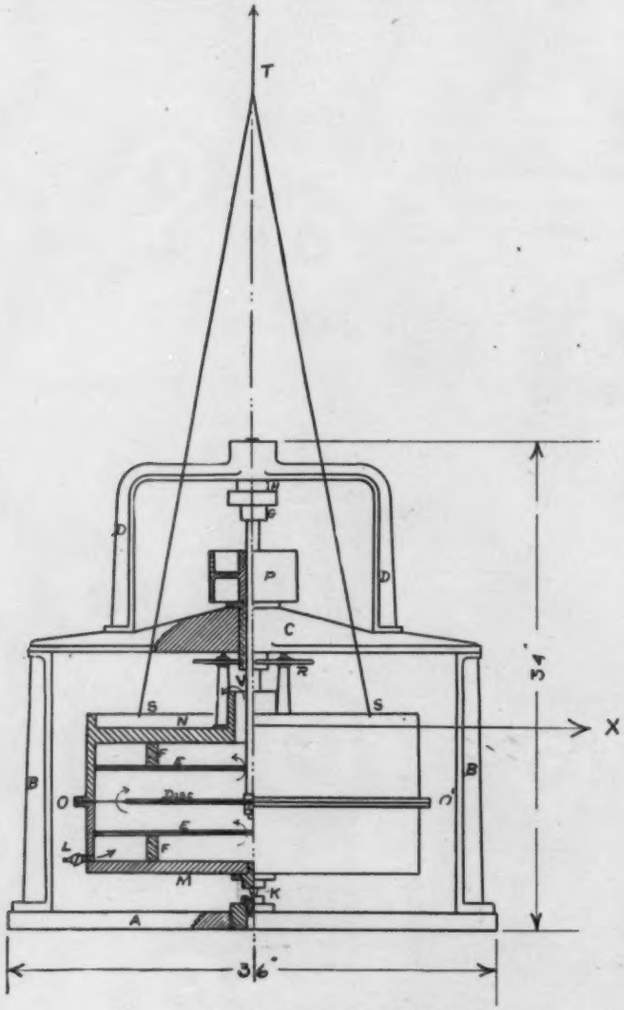

Fig. 1. Sketch of Testing Apparatus.

collar H and the pulley P. The disc rotated in the middle plane of the container, and between the stationary brass plates E E, which were finished upon the sides facing the rotating disc. These stationary plates were held in position by the posts F F, and the distance between the stationary and movable plates could be varied by varying the length of these. The joint between the stationary plates and the cast iron shell was made water tight with great care in order that no leakage or pumping action should take place there.

Power was supplied by a direct current motor to a countershaft, and then through a quarter turn belt to the pulley P. Large variations of speed were effected by changing the pulley size on the motor. A sensitive tachometer was belted to the disc shaft by a quarter turn belt on the pulley G. By means of a rheostat in the field of the motor the speed of the disc could be held accurately at a fixed value.

As the absorption of a very considerable amount of power would rapidly raise the temperature of the water, and as the friction depended to some extent on the temperature, some sort of water circulation was a necessity. This was accomplished by admitting a stream of cold water at the pet cock L through flexible tubing. The circulating water then passed through a hole in the center of the lower stationary plate, then radially outward below and radially inward above the rotating disc, finally escaping around the main shaft, and overflowing the shell at V. The temperature of the water was taken with a thermometer at V and also in the space between the stationary plates by means of an opening at O. Whatever disturbances were created by the radially outward flow below, seemed to be exactly balanced by the radially inward flow above the moving disc, as a temporary shutting off of the circulating water in no way disturbed the balance of the apparatus when running full power.

The power absorbed by the rotating disc was measured by noting the reaction of the container about its pivot K. This was done by wrapping a cord about the outside of the shell and measuring the force X with a small platform scale. If R is the outside radius of the shell, N the revolutions per minute of the shaft carrying the disc, and X the net pull on the string, then:

$$\text{H. P.} = \frac{2\pi RNX}{33000}$$

and calling $\frac{2\pi R}{33000} = K$, H. P. $= K N X$.

In the present instance K was found to be .0001788.

Six brass discs and two iron ones were tested. All the careful work, and all work involving variations in spacing, was done with the brass discs, for the reason that their surfaces were identical with those of the stationary plates, and also that these surfaces did not tarnish with prolonged use. The actual radii of the brass discs were 8 in., 10 in., 12 in., 14 in., 16 in. and 18 in., but since the cylindrical edges of the discs due to their thickness play a very important part, the velocity being highest there, the approximate virtual radii were computed by adding ½ the thickness of the plate to the radius, according to the following table.

Actual		Virtual	
Diam.	Radius	Diam.	Radius
BRASS DISCS.			
8	4	8.15	4.075
10	5	10.15	5.075
12	6	12.16	6.084
14.015	7.007	14.16	7.08
16	8	16.16	8.08
17.97	8.985	18.13	9.065
CAST IRON DISCS.			
12	6	12.47	6.235
18	9	18.50	9.25

The distance between the stationary and movable discs was changed four times. These spaces were 0.125, 0.266, 0.535 in. with the stationary brass discs in place, and 3.83 in. when they were entirely removed leaving the top and bottom of the iron shell only. The tests with the iron discs were made under these latter conditions only.

No elaborate tests on the effect of temperature on resistance were made, but only sufficient data was obtained along this line to give an approximate empirical formula by which the effect of slightly varying water temperature encountered from day to day could be reduced to a standard temperature at 65 degrees F. This was done by passing the circulating water through a coil of iron pipe heated by a large Bunsen burner, until the temperature conditions became constant. The formula assumed was:

$$(H.P.)_{65} = HP\ (1 + C\ (t - 65)$$

The coefficient C was found to follow approximately the law

$$C = a\ \frac{1}{d^n\ s^m} \quad \text{or} \quad 0.524\ \frac{1}{s^{0.2}\ d^{2.1}}$$

The manner of conducting a set of tests was as follows: The stationary discs were first adjusted accurately parallel to the parting plane of the two halves of the shell and at the correct distance apart. The shell was then bolted up, filled with water, and the shaft run at high speed without any disc. The slight torque was then measured, and was used as a zero reading, being subtracted from all subsequent readings with discs attached. This slight zero correction was due to slight errors in balance of the large mass and initial torsion in the piano wire suspension. The shell was then emptied, the two halves unbolted and the first disc attached to the shaft. After bolting up the shell again, the disc was adjusted exactly midway between the two stationary plates. This adjustment in the case of small spaces was of great importance, for if the rotating plate was not central it was powerfully drawn toward the nearer plate. This attraction was so great as in several instances to lift the entire weight of the apparatus, amounting to 150 lb. off the pivot K.

The disc was then brought up to speed and the torque noted while the speed was held constant on the tachometer by means of a field rheostat. A test at higher speed was then made and so on, the motor pulley being changed from time to time and the temperature of the circulating water being noted. After a complete set of tests on one disc, others were inserted until all six had been tried with the given spacing. In addition runs at different temperatures were made, and finally a second trial was made with no disc in order to check the zero reading.

The machine was then taken down, the posts F F cut off and a similar set of readings made at the new spacing, and so on. The results of the work are as follows:

18 in. BRASS DISC.

⅛ in. Space Speed.	Pounds Force.	H.P	True Temp. Fahrenheit, degrees.	H.P. corrected to 65° Fahr.
420	2.15	0.161	62,8	0.1604
512	3.10	0.277	63.3	0.276
626	4.40	0.493	63.3	0.4915
718	5.70	0.723	63.8	0.731
820	7.10	1.041	63.8	1.038
923	8.80	1.453	63.3	1.450
1025	10.70	1.961	62.8	1.953
0.266 in. Space.				
404	2.14	0.154	70.8	0.155
505	3.20	0.288	70.8	0.291
606	4.44	0.471	70.8	0.471
707	5.92	0.748	70.8	0.755
808	7.82	1.130	70.8	1.140
909	9.84	1.600	71.8	1.616
1010	11.99	2.165	72.8	2.192
1111	14.02	2,785	73.8	2.825
1212	16.72	3.625	74.8	3.68
0.535 in Space.				
430	2.55	0.196	61.8	0.195
505	3.48	0.314	61.8	0.313
606	4.79	0.518	61.8	0.515
707	6.26	0.79	61.8	0.786
808	7.99	1.155	61.8	1.15
909	9.70	1.575	61.8	1.568
1010	11.70	2.11	61.8	2.10
1111	14.51	2.88	61.8	2.866
3.828 in. Space.				
597	5.01	0.535	58.2	0.531
697	6.76	0.842	58.2	0.836
796	8.79	1.25	58.2	1.24
896	10.99	1.76	58.2	1.747
995	13.39	2.38	58.2	2.36
1095	16.11	3.15	58.2	3.15
1194	18.86	4.03	58.2	4.03
1293	22.31	5.16	58.2	5.16
⅛ in. Space Speed.	16 IN. BRASS DISC.			
461	1.61	0.133	65.8	0.133
513	2.00	0.184	65.8	0.184
615	2.72	0.299	65.8	0.2996
718	3.65	0.469	65.8	0.470
820	4.60	0.675	65.8	0.676
922	5.67	0.935	65.8	0.937
990	6.60	1.168	64.8	1.167
0.266 in. Space.				
606	2.78	0.301	60.8	0.298
707	3.68	0.465	60.8	0.461
808	4.76	0.688	61.8	0.683
909	6.30		62.8	
1010	7.21	1.302	63.8	1.292
1111	8.66	1.722	63.8	1.708
1212	10.10	2.190	64.8	2.172
0.535 in. Space.				
606	2.87	0.311	58.8	0.307
707	3.80	0.480	58.8	0.475
808	4.80	0.693	58.8	0.685
909	6.30	1.022	58.8	1.01
1010	7.40	1.335	58.8	1.32
1111	8.86	1.76	58.8	1.74
3.828 in. Space.				
697	4.22	0.525	57.8	0.521
796	5.54	0.788	57.8	0.782
896	6.82	1.09	57.8	1.080
995	8.32	1.48	57.8	1.466
1095	9.87	1.93	57.8	1.913
1194	11.62	2.48	57.8	2.46
1293	13.42	3.10	57.8	3.07
1392	15.52	3.87	57.8	3.84
⅛ in. Space Speed.	14 IN. BRASS DISC.			
513	1.10	0.101	64.8	0.1009
636	1.59	0.1808	64.8	0.1806
718	2.04	0.262	63.8	0.2606
820	2.70	0.396	63.8	0.394
923	3.35	0.552	63.8	0.55
1025	4.10	0.752	63.8	0.749
1111	4.78	0.950	63.8	0.946
1212	5.62	1.219	63.8	1.213
1313	6.43	1.51	63.8	1.503
0.266 in. Space.				
606	1.50	0.162	71.3	0.165
707	2.05	0.259	71.3	0.263
808	2.63	0.38	71.3	0.386
909	3.34	0.543	71.3	0.5515
1010	4.10	0.740	71.3	0.752
1111	4.92	0.977	71.3	0.994
1212	5.74	1.245	71.3	1.266
1313	6.43	1.51	71.3	1.535
1414	7.59	1.92	71.3	1.95
1515	8.80	2.38	71.0	2.416
0.535 in. Space.				
606	1.63	0.176	58.8	0.173
707	2.25	0.284	58.8	0.280
808	2.84	0.41	58.8	0.404
909	3.54	0.575	58.8	0.576
1010	4.26	0.769	58.8	0.758
1111	5.03	1.00	58.8	0.986
1212	6.05	1.31	58.8	1.290
3.828 in. Space.				
896	3.83	0.612	57.8	0.606
995	4.80	0.855	57.8	0.846
1095	5.67	1.11	57.8	1.098
1194	6.68	1.43	57.8	1.413
1293	7.72	1.785	57.8	1.765
1392	8.79	2.19	57.8	2.165
1491	9.86	2.63	58.8	2.604

12 IN. BRASS DISC.

⅛ in. Space Speed.	Pounds Force.	H.P	True Temp. Fahrenheit, degrees.	H.P. corrected to 65° Fahr.
808	1.22	0.176	64.8	0.176
909	1.58	0.257	64.8	0.257
1010	1.91	0.345	64.8	0.345
1111	2.32	0.461	64.8	0.461
1212	2.72	0.590	64.8	0.589
1313	3.20	0.751	64.8	0.750
1414	3.78	0.949	64.8	0.948
1515	4.23	1.146	64.8	1.145
1616	4.81	1.391	64.8	1.390
0.266 in. Space.				
909	1.65	0.268	67.8	0.271
1010	2.08	0.376	67.8	0.380
1111	2.60	0.516	67.8	0.521
1212	2.88	0.624	67.8	0.630
1313	3.33	0.782	68.8	0.793
1414	3.87	0.978	68.8	0.992
1515	4.38	1.185	69.8	1.206
1616	4.98	1.438	69.8	1.463
1717	5.55	1.700	70.8	1.735
1818	6.24	2.030	70.8	2.072
0.535 in. Space.				
909	1.75	0.286	56.8	0.278
1010	2.20	0.398	56.8	0.388
1111	2.77	0.55	56.8	0.536
1212	3.25	0.705	56.8	0.686
1313	3.77	0.885	56.8	0.862
1414	4.36	1.102	56.8	1.072
1515	4.75	1.285	56.8	1.251
1616	5.55	1.590	56.8	1.513
1717	6.07	1.865	56.8	1.816
1818	6.65	2.16	56.8	2.104
3.828 in. Space.				
896	1.98	0.317	59.8	0.313
995	2.38	0.424	59.8	0.419
1095	2.85	0.558	59.8	0.551
1194	3.37	0.72	59.8	0.711
1293	3.86	0.893	59.8	0.883
1392	4.38	1.09	59.8	1.077
1491	4.99	1.33	59.8	1.314
1591	5.59	1.59	59.8	1.571
1690	6.27	1.89	59.8	1.868

10 IN. BRASS DISC.

⅛ in. Space				
909	0.66	0.107	65.8	0.108
1010	0.80	0.144	65.8	0.145
1111	0.98	0.195	65.8	0.196
1212	1.18	0.256	65.8	0.257
1293	1.33	0.307	65.8	0.309
1414	1.60	0.404	65.8	0.406
1515	1.80	0.488	65.8	0.49
1616	2.08	0.602	65.8	0.605
1717	2.30	0.706	65.8	0.71
1818	2.64	0.858	65.8	0.864
1919	2.92	1.002	65.8	1.008
2020	3.25	1.174	65.8	1.176
0.266 in. Space.				
1010	0.81	0.146	68.8	0.148
1212	1.30	0.281	68.8	0.285
1414	1.59	0.402	68.8	0.408
1616	2.11	0.61	66.8	0.619
1818	2.67	0.868	66.8	0.882
2020	3.28	1.183	66.8	1.200
0.535 in. Space.				
1111	1.27	0.252	54.8	0.240
1212	1.47	0.319	54.8	0.304
1313	1.77	0.415	54.8	0.395
1414	1.98	0.500	54.8	0.476
1515	2.22	0.602	54.8	0.574
1616	2.50	0.722	54.8	0.688
1717	2.78	0.853	54.8	0.813
1818	3.09	1.004	54.8	0.958
1919	3.42	1.172	54.8	1.116
3.828 in. Space.				
1095	1.27	0.249	57.8	0.243
1194	1.51	0.322	57.8	0.315
1293	1.77	0.41	57.8	0.400
1392	2.07	0.515	57.8	0.503
1491	2.36	0.63	57.8	0.615
1591	2.70	0.768	57.8	0.75
1690	3.01	0.91	57.8	0.888
1790	3.26	1.042	57.8	1.018
1890	3.69	1.248	57.8	1.22

8 IN. BRASS DISC.

⅛ in. Space				
1010	0.23	0.042	66.8	0.043
1212	0.32	0.069	66.8	0.070
1414	0.48	0.121	65.8	0.122
1616	0.63	0.182	65.8	0.183
1818	0.81	0.263	65.8	0.265
2070	1.09	0.403	65.8	0.406
2242	1.30	0.521	65.8	0.525
0.266 in. Space.				
1212	0.44	0.095	67.8	0.097
1313	0.51	0.120	66.8	0.122
1414	0.57	0.144	66.8	0.146
1515	0.66	0.179	66.8	0.182
1616	0.77	0.222	66.8	0.226
1717	0.89	0.273	66.8	0.277
1818	1.01	0.328	66.8	0.333
2020	1.28	0.462	66.8	0.470
2242	1.58	0.635	66.8	0.643
0.535 in. Space.				
1111	0.43	0.085	56.8	0.080
1212	0.54	0.117	56.8	0.110
1313	0.64	0.150	56.8	0.141
1414	0.74	0.187	56.8	0.176
1515	0.85	0.230	56.8	0.216
1616	0.96	0.277	56.8	0.260
1717	1.07	0.328	56.8	0.308
1818	1.18	0.383	56.8	0.360
1919	1.30	0.446	56.8	0.419
2020	1.42	0.513	56.8	0.482
3.828 in. Space.				
1212	0.62	0.134	52.8	0.126
1313	0.72	0.169	52.8	0.158
1414	0.82	0.207	52.8	0.194
1515	0.93	0.252	52.8	0.236
1616	1.05	0.303	52.8	0.284
1717	1.15	0.353	52.8	0.331
1818	1.26	0.409	52.8	0.384
1919	1.38	0.474	52.8	0.445
2020	1.49	0.538	52.8	0.504

18 In. Cast Iron Disc (Clean).[1]

3.651 in. Space Speed.	Pounds Force.	H.P.	True Temp. Fahrenheit, degrees.
697	7.35	0.915	59.8
796	9.55	1.36	59.8
896	11.94	1.913	
995	14.68	2.61	
1095	17.38	3.404	
1194	20.71	4.43	
1293	23.58	5.45	64.8

18 in. Cast Iron Disc (Rusted).

705	9.51	1.198	69.3
806	12.55	1.808	
906	15.55	2.520	
1007	19.43	3.500	
1108	22.53	4.460	72.8

18 in. Cast Iron Disc (With rust cleaned off.)

705	7.43	0.936	64.8
806	9.68	1.394	
906	12.08	1.956	
1007	14.63	2.635	
1108	17.23	3.415	
1209	19.43	4.20	
1310	22.13	5.18	69.8

12 in. Cast Iron Disc (Clean).

3.651 in. Space.			
796	1.70	0.242	58.8
896	2.19	0.351	58.8
995	2.69	0.478	58.8
1095	3.17	0.620	58.8
1194	3.82	0.817	58.8
1293	4.42	1.022	58.8
1392	5.47	1.362	58.8

12 in. Cast Iron Disc (Rusted).

3.651 in. Space.			
705	1.73	0.218	66.8
806	2.33	0.336	66.8
906	2.90	0.470	66.8
1007	3.53	0.636	66.8
1108	4.23	0.839	66.8
1209	5.09	1.100	66.8
1310	5.83	1.365	66.8

[1]We had no time to make tests for our temperature coefficients. Therefore none of these results are corrected to 65 degrees Fahr.

If the corresponding values of horsepower and speed from the above tables are plotted upon logarithmic cross section paper, the points for any given disc and spacing will be found to fall upon one of a series of straight lines, which are substantially parallel. Fig. 2 shows the plot of these points exactly as observed, and corrected for temperature only. If for any given speed and spacing, the horsepower be plotted as a function of disc diameter, the points will be found to fall almost exactly upon a system of parallel lines.

If for given speed and disc diameter, the horsepower be plotted as a function of the spacing, the points will be found to fall approximately upon a system of parallel lines.

These facts indicate that the entire law of power absorbed by friction can be expressed by the relation

$$H.P. = Kd^n N^m S^l$$

Averaging over the entire series of experiments, the following mean values for the coefficient and exponents have been determined:

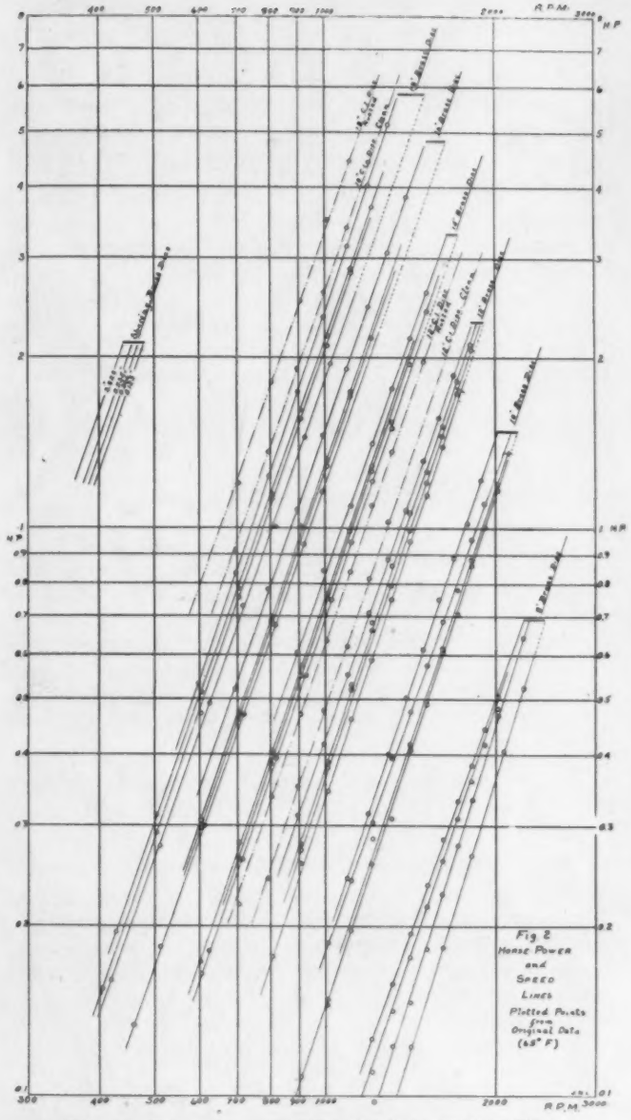

Fig. 2. Horsepower and Speed Lines Plotted From Experimental Data.

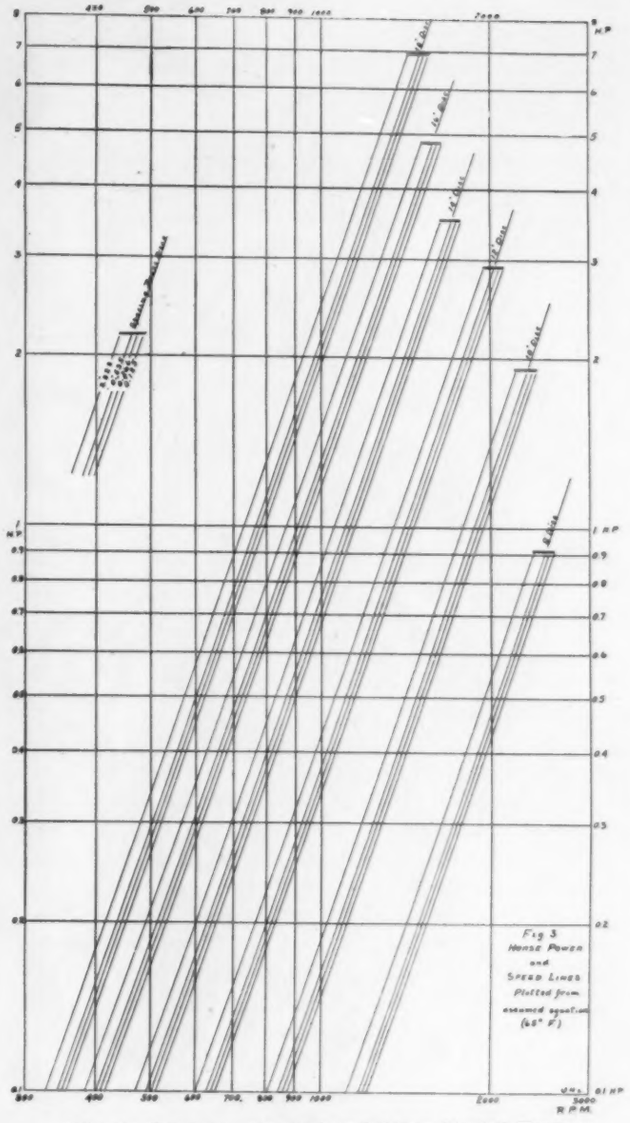

Fig. 3. Horsepower and Speed Lines Plotted From Assumed Equation.

$$K = .000,000,000,837$$
$$n = 4.41$$
$$m = 2.88$$
$$l = 0.067$$

or $H.P. = .000,000,000,837\ d^{4.41}\ N^{2.88}\ S^{0.067}$

where d is the diameter (virtual) of the disc in feet

N is the number of revolutions per min.

S is the spacing in inches.

(for ordinary machine finished brass discs).

The law which expresses the power as varying with S^l cannot, of course, be considered as holding except within the range of our experiments. For if $S = O$, then according to the above law the power would be zero, which is contrary to fact. All that is meant here is that the above law seems to hold within the range of these experiments.

Fig. 3 shows the results of plotting the assumed equation with the given values of K, m. n, and l. A comparison with Fig. 2 will give an idea of the accuracy of the assumed equation.

Two cast iron discs 18 in. and 12 in. in diameter and ½ in. thick, and therefore of virtual diamters 18½ and 12½ in. with ordinary machine finish were then tested on the largest spacing. When clean they gave practically the same result as did the brass, the slightly greater power being due principally to the larger virtual diameter. They were then allowed to stand in an atmosphere of wet carbonic acid gas till thoroughly rusted over, and tested again. The rusty iron discs consumed 30 per cent more power than did the clean ones.

If it were merely the sliding or shearing of the rotating disc in the water, and the shearing of the various layers of water upon each other which caused the absorption of power, it would be easy to formulate a theoretic law which would indicate the power to vary as the cube of the speed, the fifth power of the disc diameter, and inversely as the square of the spacing. But this sort of relative motion is clearly not what takes place. Circulating currents are set up which flow outwards along the surface of the rotating disc and inwards along the stationary plates. The intensity of shearing motion increases with the decrease of spacing, but the mass of water set into circulation increases with the increase in spacing and this latter

effect seems to slightly more than offset the former, causing the net absorption of power to increase with increasing spacing. Whether this would hold for very small spacing cannot, of course, be told without further experiment.

In conclusion the writer wishes to acknowledge the valuable assistance and careful work of the following students in the Mechanical Engineering Department, University of California: Mr. H. V. S. Hubbard, who made up the working drawings of the apparatus; Mr. R. H. Beck, who assisted with the testing of the discs in the ⅛ in. space; and particularly Mr. H. F. Fischer, who assisted in all the final testing and computed the results.

LIGNITE FOR FUEL.

North Dakota Lignite as a Fuel for Power-Plant Boilers is the title of Bulletin No. 2 just issued by the Bureau of Mines. This bulletin describes a series of tests at the pumping plant of the United States Reclamation Service at Williston, North Dakota. The Reclamation Service has a large project there and had installed steam boilers with furnaces designed to burn a "brown lignite" that was mined on adjacent government land.

The furnace is of the semi gas-producer type and has an external resemblance to the so-called Dutch oven. The most striking features in its construction are the deep-set grate and the construction of the space between the bridge wall and the end of the prolonged fire brick arch. The furnace is designed to work on the gas-producer principle. The solid fuel is gasified on the grate and the gas passes through the space under the arch into the combustion chamber where most of the gaseous combustible burns.

The results of the tests on the lignite show that this fuel, though generally considered unsatisfactory, may be used with fair economy under boilers that generate their fuel rated capacity. In fact, when the number of heat units available is considered, the results compare favorably with those of better grades of fuel.

The tests are deemed important because the lignite deposits of the Northwest are so extensive and the distance of the region from other coal fields is so great that a large portion of the United States, including parts of North Dakota, South Dakota and Montana, may be greatly benefitted by any improvements in the methods of utilizing this local fuel supply. The lignite in this field is low in heating value, some of it containing nearly 45 per cent of its weight in moisture, and it is difficult to burn in the furnaces commonly used for the better grades of coal, but the tests have shown the possibility of designing suitable furnaces for burning it profitably.

The tests were conducted by the Technologic Branch of the Geological Survey which is now a part of the Bureau of Mines. The authors of the bulletin are D. T. Randall and Henry Kreisinger. The bulletin will be of interest to fuel engineers, especially to those located in lignite territory. It may be obtained by addressing the Director of the Bureau of Mines, Washington, D. C.

THE PHYSICAL MEANING OF ENTROPY.

BY W. F. DURAND.[1]

The editor has called to my attention the following summary which he has prepared of an explanation of the physical meaning of entropy as advanced by Mr. A. L. Menzin in the Engineering News of September 1, 1910, together with discussion thereon by Sidney A. Reeve and William Kent:

In converting heat into work in a steam or gas engine there is a certain unavoidable waste, or rather transfer of heat energy even in the ideal engine. According to the Carnot principle the greatest amount of work that can be obtained from a quantity of heat Q which is absorbed by the working medium at an absolute temperature of T and the waste heat rejected at a lower temperature T_0 is equal to $\frac{T - T_0}{T} Q$. The least possible waste must therefore be $Q - Q\frac{T - T_0}{T} = \frac{QT - QT - QT_0}{T} = Q\frac{T}{T_0}$

At any instant while this heat is being absorbed an infinitesimal part of it is absorbed at a practically constant temperature T. Denoting this very small amount of heat as dQ the unavoidable waste associated with it is $\frac{T_0}{T} dQ$ and the total unavoidable waste for the total heat Q is equal to the summation of all these elements of waste. Letting L represent this total waste,

$$L = \int_0^Q \frac{T_0}{T} dQ = T_0 \int_0^Q \frac{dQ}{T} \text{ or } \frac{L}{T_0} = \int_0^Q \frac{dQ}{T}$$

But $\int_0^Q \frac{dQ}{T}$ is the mathematical expression called entropy. Hence entropy is the minimum unavoidable heat waste per degree of absolute temperature of rejection.

Mr. Menzin proves mathematically that this definition also applies to refrigeration when the temperature of rejection is higher than the temperature of absorption and also that the entropy remains unchanged when a substance alters its state adiabatically.

From this is derived a more general definition. *In the conversion of heat into work, whether of heat external to a working substance or contained within it as intrinsic energy, entropy is the minimum unavoidable waste per degree of absolute temperature at which all of this waste may be rejected by the working substance.*

Since heat waste is nevertheless heat, the unit of entropy, is one heat unit per degree of temperature as 1 B.t.u. per degree Fahrenheit, 1 calorie per degree Centigrade, etc.

The first serious objection to Mr. Menzin's attempt to give a physical interpretation of entropy is that it is based on a complex or multiple process instead of on a single or simple thermal change. If the concept of entropy is to be of any significance in problems connected with thermodynamics, it must be based on and referable to a single, simple thermal change accompanied in general with a flow of heat into or from the body.

The second objection is that it does not seem to aid very much in clarifying the situation. I doubt very much whether the statement that the "entropy is the minimum unavoidable heat waste per degree of the absolute temperature at which this heat waste is rejected by the working substance" would aid very

[1]Professor of Mechanical Engineering, Leland Stanford, Jr., University.

much in forming a physical concept of entropy, especially in the case of a simple problem such as the following: A pound of air is heated at constant pressure from a temperature of 100 to a temperature of 200 Fah. What is the change in entropy? There is no heat waste involved and nothing in the statement of the problem seems to readily relate itself to Mr. Menzin's definition. Yet it is with reference to such simple thermal changes as this that entropy must be interpreted.

In the original statement by Mr. Menzin, due to the phrasing of the definition, there was some danger of confusion between heat and entropy. This has been removed in large measure by Mr. Kent's discussion, which however does not rescue the definition from the two objections noted. In reference to the definition of the unit of entropy as defined by Mr. Menzin it must be noted that this is no more heat than a rate of pay of $2.00 per day is money. If a man goes into a grocery store to buy $2.00 worth of groceries he cannot pay his bill with $2.00 per day. He can, however, pay with the proceeds of $2.00 per day for one day's time. Thus, rate of pay and time are the two dimensions of money earned, while similarly change of entropy and absolute temperature are the two dimensions of heat flow.

No exception can be taken to Mr. Menzin's discussion in so far as it implies that in a cyclical process, the minimum unavoidable heat waste or minimum rejected heat divided by the absolute temperature of rejection will equal the change of entropy. But, after all this is no more than saying that one side of a rectangle is equal to the area divided by the other, or that one of the two factors of a product is equal to the product divided by the other. The fact is undeniable but it is not easy to derive any basis for a new physical concept or entropy from such statement. Yet this is exactly what is implied by Mr. Menzin's statement and no more. The steps are as follows:

(1) The existence of a reverse or rejection process is assumed and lying between the same limits of entropy as some other forward or heating process under consideration.

(2) It is assumed that this rejection process takes place at a constant temperature, T.

(3) Then by the fundamental concept of entropy or from any of the fundamental equations, it follows that the heat rejected must equal the product of the change of entropy by the absolute temperature.

(4) It follows that the change of entropy will equal the quotient of the heat rejected, divided by the absolute temperature.

(5) This will give the change of entropy backward or for the rejection process, and since the two assumed operations lie between the same limits of entropy, the change backward must equal the change forward.

All these facts are clear and unquestioned, but it is not clear that this imaginary complex process will aid in gathering an idea of the change of entropy for a simple heating or cooling process, such as that involved in the illustrative problem mentioned previously.

This by way of criticism of Mr. Menzin's treatment.

Referring further to attempts on the part of writers like Mr. Menzin and Mr. Reeves to give a physical interpretation to entropy, it would be well if they and all engineers interested would realize once and for all that from the nature of things such attempts must be futile, and that such effort will only result in a labored and backhanded attempt at a physical concept, which will be of small value to either physicists or engineers.

Matter as we know it possesses certain primary characteristics which we can apprehend by our natural senses in a more or less direct manner. Thus, pressure, volume, temperature and energy all present some possibility of direct sensory apprehension, or are related simply and directly to things which may be so apprehended. Unfortunately, however, we have no entropy sense, and cannot come into any direct sense relations with it, nor is it related to other quantities in such manner as to permit of any direct simple physical concept. In brief, it is not a property or characteristic of a substance which admits of direct or first hand apprehension. It is conceivable that a race of beings might be created (and perhaps may now exist on some other planet) which could directly sense the characteristic entropy. It is certain, however, that we cannot, and that all attempt to imagine or define entropy in this manner must end in fog.

Referring now briefly to the subject constructively, we may ask what is entropy and what is the most rational viewpoint for the engineer with regard tc its nature.

We may start back with the Clausius equation on which all controversialists will be agreed:

$$\text{Entropy} = \int \frac{dQ}{T}$$

Put into words, this equation simply says that entropy is the sum of a series of small elements, each of which is an element of heat flow divided by the absolute temperature under which such flow is effected. No matter how we may beat about the bush we are not likely to improve on the plain fundamental statement of fact of which this equation is the expression.

On the other hand, there are many helpful analogies. Thus entropy stands in exactly the same relation to heat flow that volume does to the work performed by a body changing volume under pressure. In one case, we have

$$W = \text{Work} = \int P\, dV$$

$$V = \text{Volume} = \int \frac{dW}{P}$$

In the other

$$Q = \text{Heat flow} = \int T dN$$

$$N = \text{Entropy} = \int \frac{dQ}{T}$$

This analogy followed out will be helpful to many. Thus, at constant pressure, work is equal to the product of pressure by change of volume. At constant temperature, heat flow is equal to the product of absolute temperature by change of entropy. At constant pressure, the two factors of work are pressure and

change of volume. At constant temperature the two factors of heat flow are absolute temperature and change of entropy. At constant pressure the change of volume equals the work divided by the pressure. At constant temperature, the change of entropy equals heat flow divided by the absolute temperature.

Or again, change of entropy bears the same relation to quantity of heat flow into or from a body that time does to the earning or spending of a sum of money at various rates per day. Thus, a man earns $100 as follows: $10 @ $2.00 per day; $35 @ $1.75 per day; $25.60 @ $1.60 per day and $29.40 at $2.45 per day. What is his time of work? Ans. Time = 10 ÷ 2 + 35 ÷ 1.75 + 25.60 ÷ 1.60 + 29.40 ÷ 2.45 = 5 + 20 + 16 + 12 = 53 days.

A body receives 1000 heat units as follows: 100 at an absolute temperature of 500°; 400 at an absolute temperature of 600°; 300 at an absolute temperature of 450° and 200 at an absolute temperature of 800° What is the change in entropy? Ans. 100 ÷ 400 + 360 ÷ 600 + 280 ÷ 700 + 260 ÷ 520 = .250 + .600 + .400 + .500 = 1.75.

In this sense the number of days' work represents the entropy of a man's earnings. These analogies followed up will be of much help in apprehending the relation of entropy to heat flow and in understanding its usefullness in thermodynamic problems.

From an entirely different viewpoint, we may acquire a somewhat different side light as follows: For a perfect gas (of which air and all the so-called permanent gases represent practical illustration) it is easily shown that the entropy is related to pressure and volume by the following equation:

$$N = C_v \log P + C_p \log V$$

where C_v and C_p are the two specific heats of the gas, one at constant pressure and one at constant volume, while P and V are the pressure and volume. Now we may consider that entropy is simply a secondary or derivative function of the well known characteristics of a body, pressure and volume, and related to them by the above equation, in just the same manner as we may consider area, volume, momentum, moment of inertia and kinetic energy, as secondary or derivative functions of geometrical dimensions and of mass. It might happen that all sorts of secondary functions of pressure and volume or pressure and temperature or temperature and volume might be useful and might require names. Thus, we might imagine a possibility that the ratio P ÷ V for a substance would acquire peculiar interest and call for a name and we might agree to call it Abracadrabra or anything else. Now we cannot readily form a direct physical concept of pressure divided by volume, at least beyond the direct statement as a quotient. Because we cannot, however, there is no need of endowing this ratio or function with anything mysterious or difficult, or of striving against hope to gain a direct physical interpretation of that which has none. We should simply accept it as a secondary function of pressure and volume and be content.

In the same manner, we may accept the preceding equation as simply an equation defining for a perfect gas a function of pressure and volume which is useful for many purposes, and which we agree to call by the name of entropy. The one case is parallel to the other.

For steam we do not have any such simple expression for entropy. Approximately, however, it is represented by the following equation involving temperature and dryness fraction or quality.

$$N = \log_e \frac{T}{492} + X\left(\frac{1435}{T} - .695\right)$$

Where T is the absolute temperature and X the dryness fraction. This may be considered as an approximate expression of relation on the one hand between temperature and dryness fraction or quality (both of which are familiar characteristics) and entropy on the other, which is thus defined as a secondary or derivative function.

In the case of both of these equations it is easy to show in the one case exactly and in the other approximately that they are consistent with the more fundamental relation that for any thermal change

$$N = \int \frac{dQ}{T}$$

This after all I believe to give the best point of view, and if we will simply accept this with its physical interpretation as a summation of small elements each of which is of the nature of a quantity of heat flow divided by the absolute temperatures at which such flow is effected, and accept such side lights and analogies as those mentioned above, we shall rest on sure ground, and shall not invite the fog and haze which must necessarily surround any attempt to consider entropy as a direct physical characteristic, or as capable of any more simple statement in terms of the other characteristics of a substance than that involved in the fundamental defining equation as given above.

ELECTRIC POWER IN MEXICO.

The Central Mexico Light & Power Company, through an affiliated company, has extended its line to San Luis Potosi, transmitting 4000 h.p. from waterfalls in the State of Michoacan. The Central Mexico Light & Power Company, organized in the State of Maine, with a capital of $2,750,000 gold, is controlled by Americans. The company has bought out the local electric company and will supply light and power to various industries. The concession from the State of San Luis Potosi provides that the company shall install a system for the distribution of electricity for purposes of mining, smelting, agriculture, and public works, shall facilitate irrigation when possible, shall encourage the introduction and development of industrial enterprises, and place its electric power at the disposal of the State and municipalities. In exchange the cities will enjoy a reduced rate for current. It is stipulated that the company shall always be regarded as Mexican, subject to the laws of San Luis Potosi, even though the owners may be foreign; that they shall never appeal to foreign law nor make claims through diplomatic channels, under penalty of forfeiture.

THE PROBLEM OF TECHNICAL EDUCATION.

Discussion by members of the San Francisco Section, A. I. E. E., October 28, 1910, of paper by S. B. Charters and W. A. Hillebrand as pubulished in this journal Nov. 12, 1910. The following took part in the discussion:

S. J. Lisberger, Engineer of Distribution, Pacific Gas & Electric Company, Chairman.

C. L. Cory, Professor of Electrical Engineering, University of California.

Harris J. Ryan, Professor of Electrical Engineering, Stanford University.

Orion Brooks, Superintendent Heald's School of Mines and Engineering.

R. W. Van Norden, Consulting Electrical Engineer.

A. H. Halloran, Managing Editor Journal of Electricity, Power and Gas.

K. G. Dunn, Vice-President Hunt, Mirk & Co.

W. A. Hillebrand, Associate Professor of Electrical Engineering, Stanford University.

C. L. Cory: The paper this evening has interested me very much, and I do not know why it should not, because I have been connected with universities and the technical side of the same for about twenty-five years, not only as a student in more than one university, but as an instructor as well in more than one. I have also been in the position of employing and utilizing technical graduates and have been responsible for the character of their work as well as of the men who are not university graduates. In addition, I have been called upon to recommend men for certain positions where the requirements were sometimes specific and in others general.

In the paper this evening there has been presented to us an appeal to the student, as well as to those employing university graduates, asking, first, that the student shall not have a false idea as to what he will really be after he has completed his college course, and second, that those who of necessity employ university graduates may not expect too much of them.

I am convinced to begin with, that in many of our technical educational institutions the instructors connected therewith seem to impress the students with a view point regarding themselves that is absolutely wrong: "A man's a man for a' that." It does not make any real difference whether a young man is educated in the small college or the great university, or gets his education by experience in the world. Results only will count.

Once I had an old colored man working for me, and when I was going away to make quite a long trip and he was driving me to the train, he said: "You know, Mr. Cory, when you're here I know's that you takes all responsibility, but now you's goin' away and I just wants you to know that I's goin' to take that responsibility."

It would be a good thing if all university graduates had the spirit expressed by that old colored man. I find many of them have not. The kind of a man who is worth while is the fellow that will do the thing you expect him to do, whether you are there to tell him how to do it or not, and the technical education as it is given and received in many universities is not such as to impress upon a man that it is his business to do the thing that he is told to do and do it no matter what the difficulties are. That is what the employer wants and what he has a right to expect. He may not get such service from the student the first year of the latter's outside career, but the employer has a perfect right to expect that a college man will see things to do without being specifically told to do them; that he accepts responsibility and will do the thing he is expected to do. I have many times thought of some of the members of my classes at the university something like this:

"You have been sent to the university and now you have nearly completed the course. Some of you have been so unfortunate as to have a fond and devoted parent who has considered it a good thing to take you to some nice summer resort and give you a lazy and pleasant time during your vacation. You have been sent to the university, you did not come. During your college course your first idea was to enjoy yourself. You haven't experienced that thing which is of the greatest importance in the development of character. You never have had responsibility placed upon you, and when you get out into the world you will find that many people who will try to use you will soon find the weakest side of your nature, and they will not care so much what you know as what you can do if left to your own resources."

I have found, and I know many others who have employed university graduates as well as other men have found that it is entirely futile to put responsibility upon a fellow who does not know what it means, and it is not long before one concludes that satisfactory results under such circumstances are impossible.

It has been implied in the paper this evening that the university training only occupies about four years of a student's time, and either before or during this period he may have been handicapped for various reasons. In my opinion it has not been a handicap because he has had to work. That is an advantage. If he has a good mind it is the business of his instructors, both in the preparatory school and in the university, to train that mind and to give him, when he has completed his university work, a mind capable of consistent and accurate work. He should have the ability to analyze a situation and finally come to something like a reasonable conclusion. Such a man will have no difficulty in seeing things in their true perspective, and will do the things that should be done whether somebody has given specific instructions to do them or not.

My experience leads me to the conclusion that the university has the best period of a young man's life. More often than otherwise it is the time when he gets away from certain very delightful but nevertheless sentimental home influences. When he comes to college he finds that he is simply one individual among a great many. He is not spared because he happens to have been more protected than his fellows before he came to college. Perhaps he has been so unfortunate as to possess relatives and friends who think he is a genius. In all probability he is not. He finds he has to work. Fellows at college should at once find this out. As a freshman he will learn many things he never could learn at home. He may learn from a senior, perhaps from a junior, or maybe from a vigorous bunch of sophomores.

It is the task of the instructors in the university to develop this young man, and the instructors have the best chance because he is at this time changing from a youngster into a man, and he should, if he is the right sort of a fellow and has been given the right kind of an example by the university instructors, develop into a keen thinking, healthy, vigorous man. The environment of the university in the class room and out will have much to do with the proper development of such a student.

Referring specifically to the teaching of electrical engineering, I happened to read for the second time a few days ago Professor Sheldon's article which appeared in the April Proceedings of the American Institute of Electrical Engineers, in which he made an appeal for some sort of an institution which should produce leaders in electrical engineering, and he cited the fact that at West Point the government has an institution for the training of young men in military science and that it has not been difficult for that one institution to produce enough leaders to take care of all of the soldiers of the United States Army.

As I read Mr. Sheldon's paper I recalled a story told not long ago by Professor Pritchett in which he described a game of baseball between Harvard and West Point, his son being a member of the Harvard nine. It seems that the Harvard team, on its spring training trip, had been traveling in the South, and naturally having a very lazy and enjoyable time. Their diet had been most carefully prescribed. They had gone South so as to be able to practice in that warmer climate. They had

been under the care of their trainer, who had taken the best of care of them, but behold the result of the game with the soldiers of West Point, who had had not more than half an hour each afternoon to practice. The Harvard team was beautifully skinned. Professor Pritchett thought the reason was because of the discipline and development among the men of West Point. They had not had time to loaf and be entertained by the various college clubs of the South. Perhaps the leadership of West Point graduates may be ascribed to discipline, at least in part.

Our attention has been drawn this evening to the university and its responsibilities, and I for one deplore the fact that in some institutions the student is given a rather bad example by the faculty in the announcement of innumerable one-hour courses, presumably with the idea of giving the impression that the whole field of electrical engineering is completely covered in the college course. In college these courses are soon nick-named "paper courses," and while many of them may be given, yet the real basis of such courses seems to be that of giving the student a certain amount of detailed information about some specific phase of the general course in electrical engineering. Many such courses are unimportant, and I firmly believe that the university and university courses have but one great object, and that is to teach the young men fundamental principles. I doubt the sincerity and am somewhat suspicious of any institution that pretends to give the student a lot of information. I am lead to that conclusion as a result of many discussions with graduates who have been out of their universities not one year but five and even ten years, and from men who have been doing something in the engineering world.

Universities might well give a better example to their students in connection with the method of teaching many engineering courses. I should be just as willing to go to a surgeon and expect that surgeon to successfully perform a capital operation on me if he had studied the science of surgery in a correspondence school only, as to expect some engineering instructors to successfully teach engineering when they have had no knowledge of engineering first hand and no real engineering experience of their own.

In order to be a teacher you have got to know the thing about which you are teaching in such a manner that it is a part of yourself, and such knowledge does not come second hand. Some instructors before a class present matters that they have dug out only a few days before, and such instructors are soon classified by the students about where they belong.

The only way to be a success as an instructor is to inspire the students with the belief that the thing you are trying to help them with is worth while, and as a proper training I would recommend to engineering instructors that instead of standing before a group of young fellows, the difference in age between themselves and the students of each class constantly increasing, that they try the experience of presenting to a board of directors some engineering proposition where he must not only know intimately the facts he is presenting, but must be prepared to prove every statement. He will find the latter job different in many ways than teaching a class. In the end the students can be depended upon to size up the instructor about as well as the board of directors will their engineer.

In our universities we should give to the students every influence that is uplifting and that will tend to make men of them and make them worthy of accepting responsibility, to give them decision and judgment, and in this connection it must be remembered that all that is of value in the university is not confined solely to the class room. There is a general atmosphere around every university which tends to develop the student in one way or the other, and the faculty to a large degree is responsible for the proper kind of this spirit.

Reference was made in the paper this evening as the opinion of one man that no matter how much the university graduate receives he will be overpaid. I do not agree with any such statement. It will naturally depend upon the university graduate. It may be true that he will be paid more than he earns for a short time, but I personally am quite willing to defend the general statement that if the university graduate is of the right sort and is given a chance the employer will find that no matter how much salary he receives he will be under-paid, because his services will be worth more than can possibly be given him in dollars if these services are characterized by a consistant loyalty, industry and a reasonable degree of originality.

The problem is: what can a university do to develop such desirable characteristics in its graduates? I believe that every university can do a great deal in this direction. One of the first necessities is a thorough confidence and co-operation between the members of the student body and the faculty. Absolute honesty on the part of each toward the other will go a long way toward relieving the present situation and eliminating difficulties unquestionably sometimes existing.

I firmly believe in military science in the instruction of students. It tends to develop characteristics not necessarily brought out in other courses. At the age of the ordinary university student regular military work can not but do him good. Not long ago at luncheon I heard a member of this section say that in the development of character military precision in the child was desirable. He happens to be the chief executive of one of our large corporations, and some one at the table said something of his experience in his youth, and he replied: "Well, I remember our home was a sort of a military proposition. We children were always very happy and we certainly had a joyful time, but there were certain requirements that we lived up to in precise military fashion," and in conclusion he stated that such success as he has had as an executive is largely due to the kind of training he had received from his parents in his early youth.

I personally remember when I wasn't much more than a foot high I used to hear something like this: "Every boy ought to have three things, habits of industry, habits of economy and a good education." These three desirables were the hobby of the best teacher I have ever had the good fortune to know—my own father—and while as a youngster the development of habits of industry and economy and acquiring a good education didn't impress me very favorably at all times, yet now I can see the wisdom of such a trinity, and I am willing to leave it to you this evening if a fellow has really developed the capacity to work effectively, knows how to economize not only in materials and money, but also in time, and has a good education, he is pretty well equipped to be of valuable service to his employer.

If a fellow is working for a corporation and is instructed to get a certain piece of work done at 8 o'clock in the morning, if he doesn't get it done there will be trouble, but on the contrary, in many of our technical institutions if a certain problem is assigned and the work is not completed on time the student will make the excuse that he lost his books, was sick, or some other terrible calamity has overtaken him, with the result that he is given as much time as he likes for the completion of the assigned work. The fellow under such circumstances should kick, because he is not getting the proper discipline to develop him, so that he is going to be worth while to somebody and to make him appreciate to a reasonable degree what is meant by responsibility.

One of the requisites of a good education is the possession of a trained mind and the ability to tie yourself down to some particular piece of work and do that work whether it is pleasant or not. Not that technical education should be a mere grind, because I believe that in engineering institutions every possible incentive should be given to individual and original work. Those of us in the university are delighted to find men, yes, boys even seventeen years of age, who have unquestioned originality, sometimes purely mathematical in tendency, but nevertheless of value to the engineer. In others this originality is manifest in experimental work, and all such men should be encouraged and never discouraged. They should be given every possible oppor-

tunity, and instructors might well remember that in their relations with students certain general characteristics may be reflected sooner or later in their students.

The young college graduate in the large corporation does not have an easy time. The freedom which he has been used to in college he misses, and in its place finds only the rigorous lines of the complete corporation organization, and it often seems the part he has to play is exceedingly unimportant considering the ability which he thinks he has. But I am inclined to think that our universities, which are giving so much attention to the technical work of their students, might do much to remove the criticism that comes from the men who employ university graduates, and this probably can best be done by improving the poin' of view of the students themselves.

In this generation I am inclined to think that many times the parents of a young man desire him to get an education, after having had a hard struggle themselves, so that he will not have to work as hard as they have. Now just as soon as the boy can get that idea out of his mind the better off he is. The more training you have had, and the greater opportunities which you have enjoyed means that the harder you have got to work. It may not be the same sort of work that you would have done if you had not been so fortunate as to have had the opportunity of obtaining an education, but the work you will do will not be according to an eight-hour schedule or the character of work to which you can apply a uniform wage. The hours will be as long as are necessary to do the work, and to do it all in the most loyal manner and use your entire ability with the idea of helping to the maximum the man to whom you are responsible.

Regarding the length of the college course, it is a fact that at the University of California now we have five-year engineering courses and also four-year engineering courses. Not long ago we decided that we would give every student who came to us his choice. He could arrange his work if he chose so as to graduate and obtain a degree in four years. Since this time we have had one young man who graduated from the electrical engineering department who completed all of the courses required for graduation in electrical engineering, and also obtained at the same time a degree in the College of Letters, and all this was done in the four years of work. He entered the university with all the requirements of the College of Letters, and he carried through his university work and graduated as the medalist of his class, and, justly I think, received the two degrees at the same time. It must be admitted that he was a rather extraordinary type of man, but many institutions are recognizing that for a certain type of individual a five-year course is better than a four-year course, and I am inclined to think that the time is not far distant when at the University of California it will be possible for a man to take an engineering course and spend six years in so doing. He will do in that time about the same work that the ordinary student will do in the general culture courses so called, and also it will be possible for him to complete all of the engineering work required in the present four-years course. Such a man, if he is the right sort, should never find a stopping place. He should, I think, by his training be so equipped that it will not make much difference whether his work be of a public nature, that of an executive or exclusively engineering. He will find that he will never be handicapped by a lack of preliminary education. On top of his university work however, must be the broader training of experience, and on the outside he will meet many instructors among his fellows who will teach him many things that he could not learn in any possible manner in the university.

I think when the university which is responsible for the training of its technical graduates finds it necessary to make excuses for its product when they get out into the world, can only blame the training which has been given the students. On the other hand, it is not right that employers should hold the university responsible because their graduates lack a lot of detail information which experience only can give, but if the employer finds that the graduate is deficient in fundamental principles and is also deficient in a desire to be loyal and do his work properly and to work 24 hours a day if necessary to do the thing that has been assigned to him, I am inclined to think that the university is decidedly responsible for the failure of such a young man, providing the university has had entire charge of his work throughout his course, whether it be for a period of four years, or five years or even longer.

Harris J. Ryan: I have read with much interest the paper by my coworkers on technical education. They have given us frankly an instantaneous view of a passing array of related factors that combine to make up the task of the teaching engineer as it exists today. They have made clear that it is proper and right to expect of the college improved results in training the engineer. They have made equally clear that the results which are most desirable can be secured only through the active and cordial co-operation of all concerned: "student, teacher, parent and employer." These results depend not so much upon the normal time required to complete the curriculum, nor upon the contents of that curriculum. They depend much more upon the real spirit of the student and his teachers and what is most important, upon the influence exerted upon the student by his parents, employer and friends.

If the engineering student comes to his graduation with a start in the essential elements of knowing, thinking and doing—if he has acquired a wholesome spirit of "usefulness, activity and co-operation," he will not go into intellectual and working stagnation. He will meet things as he finds them, take hold and make good. Now these are the results that our friends in practice rightly demand. We know that while the quality, character and length of the curriculum are a help when rightly chosen yet they amount to little compared with the fibre of the young man himself. This fibre is the integral result of all factors. Heredity, home and community, school and college, and the early appreciation of the true grit that practical life demands of the successful.

For 22 years more or less the young man has been supported and educated by his parents, friends, community and college. Habits that are long in forming are correspondingly difficult to break, yet the engineer-graduate is asked to break suddenly this deeply rooted habit of dependence upon others for most things. It is a habit that is as old as himself which he must break the first day after his commencement and to substitute therefor the habit of work and discipline that the industrial worker spent eight years to acquire. It is not creditable to our intellects if we expect the engineering graduate to make this transformation in a single day or month and do it well. Better is it, that we should now realize the difficulty we put upon him and help him to meet it. In college we are, in all wholesome ways of which we can conceive, helping the young man from his freshman year to prepare for this transition. You, gentlemen, in practice, can accomplish as much or more in this matter than we can. You can give the college boys vacation work, and work for those who must for a year or more, interrupt their studies to earn their living.

If we could have our own way in these matters we would require of the young man at entrance, that he must have earned his living in a *bona fide* manner for one year.

It is by no means a misfortune to a student when he must drop out for a year to earn his living, especially between his sophomore and junior years. Such an experience tones up his wisdom in a most desirable fashion, though doubtless upon his return for a brief time interferes with his ability to "cram" his work.

We can do nothing better for the cause of technical education than to insist that better results must come largely through a loyal, hearty co-operation of student, teacher, parent, engineering friend and employer.

Orion Brooks: I came here this evening not to speak but to hear what was said; but from the paper that has been read,

and particularly from Professor Cory's remarks, I feel that I ought to say a few words on the subject, and my remarks will be rather those, you might say, of a rank outsider as regards universities.

In order to put myself straight I might say that for about twenty years I was engaged in electrical work, and had occasion to supervise and employ quite a number of people in that work, and I found it extremely difficult to get people who would do the work that was naturally expected of them. It was quite a common thing for parents of young men to appeal to me to take their sons as students in the work room. Now if there is any thing that is an infernal nuisance in a business it is the student; and many times it was rather difficult to say that I would not take them.

Finally the wheels fortunately turned in such a way that I was in circumstances so that I could entertain the proposition to undertake to carry on a plan for giving electrical instruction to young men who could not go to the university for one reason or another, or who would not go (whether they could or not); I took such people, and endeavored to give them the essentials of an electrical education. The first difficulty that I met with, particularly with the average student coming from the grammar school, or from the high school, was that his training so far had been such as to encourage him to lean on some one else. About the first thing that I had to do was to get him to stand on his own feet, to think for himself. He had been accustomed to letting some one think for him. First I made him think for himself, and then started him on the subjects that he wanted to take up—if he knew what he wanted, and very often he did. Some very bright men came under my care; and many of them, I am proud to say, did well.

But the method of instruction and the method of handling them was so entirely different from what I understand is the case in the universities, that you can hardly draw a comparison. Still this one feature crops up above almost everything else—that the young man must be made to stand on his own feet and think for himself; and then it remains for him to determine where he will land, whether it be at the foot of the ladder or at the top. There is no end to the study; and sometimes I have thought that if a person spends four or five or six years in an educational institution he is getting into a line of thought that is going to receive a very severe jar when he gets out and undertakes to make his way in the world. If he gets that jar a little earlier it would perhaps be better for him. Make him stand on his own feet; think for himself; and then point the way to him and see where he will land. That has been my motto.

S. J. Lisberger: Professor Brooks has made one remark that I know more than one of us nodded our heads at, namely, that the student in business is a nuisance. It is quite true that we are very often met by friends, who say, "My boy has been wiring bells around the house, and he thinks he would become a electrical engineer." They give absolutely no thought to what the science of engineering is. They do not know, and the man himself may be far better fitted for a commercial life than for that of an engineer; and the greatest misfortune is that it usually takes him five years to find it out. Then his father thinks he has expended much money in educating him, and he hates to see his boy give it up.

Professor Ryan is quite right when he states there is the duty of co-operation on the part of all concerned, teacher and employer.

I recall a case in my senior year at college that gave more than one young engineer a chance for thought. Our instructor at that time was none other than Professor D. C. Jackson, now president of the Institute. On the first course in alternating currents he spent weeks, if not the whole semester, in drilling into the class the rudiments of alternating currents; and just before examination time he ended up his little course by saying, "We have now read the preface to the book. The rest is merely a novel." He came in examination morning, his hat and coat on, evidently very much in a hurry. "I have to catch a train for Chicago. Will one of you boys write these questions on the board? Deposit your papers Friday. You may use the library. You may talk to each other, and whenever you quote an authority from a book give me the reference. All I ask you is to be honest with me." We spent three or four hours finding out that there was nothing we could learn from books. It was merely a question of think, and you had to think out question No. 1 before you could answer question No. 2, because the answer to question No. 2 depended on the answer to question No. 1. It was a great lesson to all, for it opened our eyes to the fact we had to "think."

R. W. Van Norden: This subject is particularly interesting because, aside from the fact that the paper is an able one, from the professor's point of view. it introduces a sociological subject which is remarkable, in that it has not been more widely discussed. It seems to me that the college point of view of the imparting of a technical education is the constant attempt to solve an abstruse problem, when as a matter of fact, the solution, is extremely simple. It is like a man who has had a break-down with his automobile; he has taken out the carburetor, and then the timer and then spends three or four hours on his back and finally when he gets up he finds that he has the key of the battery switch in his pocket.

Mr. F. V. T. Lee said in a lecture before engineering graduates, that when they went to work at their profession not to be disappointed at receiving but small pay, as they would be worth less than they received, no matter how small it might be.

I do not believe that any college ever has, or ever will, or ever can turn out an electrical engineer. I do not mean to infer by that, that there is anything lacking in the training, because I believe that in order to become an electrical engineer a man must have a college training. But to refer to the example given a moment ago, of the automobile; the college is attempting by every art and device and the most strenuous work on the part of the teachers, to turn out a completed electrical engineer.

It cannot be done. He may, after he has been out a short time, as Professor Cory says, be worth a great deal more than he can command. But he has gotten something that he could not be taught in the class-room, but which the class-room enabled him to attain.

The college discipline and training, with its pursuit of various studies, many at the time seeming to be foreign to the desired object, has given him just one thing—not Ohm's law or certain abstract formulas in mathematics or certain highly theoretical antics of alternating currents, but the ability to think. He has specialized in order to think correctly along specific lines.

I do not approve of many of the methods that are in vogue in imparting technical education, among them I refer particularly to the examination system. But I appreciate that it is a necessary evil. Examinations are necessary to make a portion of the students work. Mr. Lisberger's example of a logical examination illustrates the point.

If a capital operation were to be performed either on a friend to whom I had been intrusted the securing of the services of a surgeon, or upon myself, I would not think of engaging a graduate surgeon, fresh from his college. Neither would I care to have a recently graduated dentist treat an ulcerated tooth. I would employ the best surgeon or the best dentist within my knowledge, that is, the one whom, from a knowledge of his experience, I had the most confidence in.

If, on the other hand, he were not a college graduate, I would not employ him under any condition.

Professor Brooks has remarked that a man must learn to think for himself. This is the same idea in a slightly different form. He must learn in the abstract, how to think, and then he must apply this action, just as a machine is first built to do something that could not be done without the aid of the machine and then the machine must be operated to get the results.

In college, the student does not think for himself; the professor does this for him. He gets ideas and they are gradually lined and connected up for him. He does not appreciate this

until he gets where that line must be put in motion; when he must think for himself.

Some time ago I read an article which was an illustration of the helplessness of the technical graduate in making a simple repair, readily accomplished by a man of practical experience. The latter had worked in a shop four or five years, he had learned how to wind generators and transformers and his skill was unquestioned. He could not have designed the machines and his movements followed certain prescribed rules of practice; these he had learned well. In the illustration, he is given the job of connecting the primary winding of an induction motor. This he does properly as he has done many others. Suppose however that the graduate be given the same job. This motor, let us assume, is different in appearance from the one which he was shown how to connect while in college and it has perhaps been badly burned and otherwise damaged. After having wasted considerable of his employer's time, he will be probably taken off of the job having accomplished nothing. But give him two weeks in the shop, and the technical training will come to his aid; he will figure out the proper manner of connection and will soon be as good a workman as the man who has taken years to learn. That man however, unless he be a genius will stay by his trade indefinitely, but the college man will pass on to something better, until step by step he becomes an engineer in fact.

What then are the qualities required to make an engineer? The untutored, but practical, man says, he must be a practical man. The technical educator says, he must have the theory and the knowledge contained in books and admits that he must have a certain amount of practical knowledge, which he attempts to impart. As a matter of fact, he must have both and yet that is not enough, he must have a third class of learning which seems to be overlooked, or if it is not overlooked it is merged into the other two classes until it often becomes indistinguishable, but it is in reality more valuable toward making the real engineer than either of the other classes.

This quality, I scarcely know how to name, but for want of something better, will call it *psychological*, it is that whereby results are obtained, things are made to go, men are efficiently handled; the application of judgment, common sense, or the discerning ability of knowing how to the right thing at its proper time and of how to use the theoretical and practical knowledge, already received, in doing so.

You have all possibly known of some man, who apparently absorbed the facts taught him in college, who graduated with high academic standing, and who, it may be, took a practical course in the shops of one of the great manufacturing concerns and was therefore, from the ordinarily accepted point of view, a thoroughly equipped engineer. But when it came to making a career as an engineer, even after several years of work and plodding, he failed to more than eke out a bare existance, if he were honest in his work and his dealings toward his clients. The man had all of the practical training necessary and his technical training was as good or better than the rest of his college class. He could not do things, or he did not apply himself aright, or he lacked judgment in every day affairs and failed to get results. He lacked that quality necessary to make an engineer, to do the right thing when something happens.

This ability can be developed, to a lesser extent it is true, in the untrained man, provided it is in his system. I have often told men over whom I had supervision in operating work, that their advancement and welfare did not depend nearly so much on their knowledge of Ohm's law or of how to make an intricate meter connection as on the common sense and judgment in doing the right thing when a series of heavy short circuits come in late, on a stormy night.

That is but an example, but may be multiplied in many ways to illustrate the point. A man who has not had a college education can and will bring out the psychological sense, if it lies dormant within him; if it is not there, it cannot be trained into him through any practical application. If, on the other hand he gets the college training and the method of correctly aligning his thinking, the psychological ability will show itself very quickly when the necessity for it to do so arises, if, as in the other case, it is in his system. If it is not in his system, a certain amount of it can be trained into him, because, he has been taught how to think.

The question of the length of a college course, or rather of lengthening the present course of four years, seems to me not to be as important as some professors deem it. The course depends somewhat upon the temperament of the student. Some students have been known to get through in two years, others take six. It would be manifestly impossible, at least with present methods to have a different course for each student and it would be further impossible to decide what that course should be.

Four years covers the various subjects in a general way and should give the average student the training he is after.

The continuous training in a good many directions should, and I believe does, as a rule, give the average man what he is really after.

The fact that a man does not do brilliant work or cannot get through in four years, is, I believe of far less consequence than it is ordinarily held by educators. The failure to pass examinations or even to absorb many of the abstract facts which are presented to him is by no means an indication of a man's failure as an ultimate engineer. Examination failures, where the student is honest and has put a reasonable amount of thought on his work, seldom indicate the failure to grasp the subject because the students conception may be illustrated in his mind's eye in an entirely different manner from that of his professor. The training is received no matter what else is absorbed and that is what is required.

A return for one or two years of postgraduate work, after one or two years in touch with operating or field conditions would undoubtedly enable the student to get a far greater grasp and understanding of advanced studies than if the work were taken immediately following his graduation.

A technical graduate generally knows, in a hazy way, about what he is going to do to commence on his professional career, but in many cases, probably a majority, he gets into a line of work in which the studies which he pursued with the greatest diligence and the facts and formulas derived therefrom are of no apparent service to him.

There was a technical graduate of my acquaintance, who, when in college made no great records. He was a fair average student but not one for whom his professors predicted an especially brillant future. A year after he graduated he obtained a good position, with an excellent salary for a young man. In another year he was advanced and in a year or so following held a position of great responsibility and was known at home and abroad as an engineer at the top of his profession. Soon after he had his first position, I met and talked with him and the conversation drifted to the subject of college training and I asked the question: "How much of what you learned in college has been of active benefit to you in your business?" His answer was that he had found none of it useful. "Then did any of the examinations for which you crammed cover problems that you meet now?" The answer was in the negative. "You graduated as an electrical engineer, are you following that work now?" "No," was the reply, "I am a civil engineer." "But," I protested, "you learned little or nothing that would specialize you as a civil engineer; how did you get into it; how did you start?" The reply was, "I scarcely know; I was told to survey, examine and report on a great property. I just used my common sense. I had to make a survey and so I bought a couple of standard books on the subject and spent two or three evenings studying them and then it was easy. I set up my transit where the boys would not see it to become more familiar with it and then I went out and told them how to make the survey. I obtained all I needed out of my books, used common sense, made the survey and did it

right and before I knew it, I was chief engineer."

In saying that nothing received at college had benefitted him, he had done his college training a great injustice, because it was that training that had made it possible for him to achieve his remarkable results. Neither theoretical or practical knowledge had helped him, because the former was foreign to his work and the latter he did not possess. But the power of correct thinking had been developed to a high degree.

I have observed many cases of men who in their work and especially examinations, seemed almost stupid, who did not appear to grasp the work or performed it in a perfunctory manner, who apparently seldom listened to what was being told them and who upon entering their career made good, achieved results and were well rated in the profession. This argument would not, of course, apply to the class dunce; there are always a certain number who will either flunk out because they cannot be trained or who will switch to something else. The professors duty is not in trying to wring blood out of a stone but in conscientiously following his work, imparting, so far as he can reasonably do so, the facts and principles to those of his students who are sufficiently interested to listen. The men whose brains are receptive consciously or sub-consciously will derive their mental training just as rapidly as they are able to receive it and no faster.

Finally, I think that Professor Charters admitted my contention, that no college could turn out an electrical engineer, when he said that it was absolutely impossible to give what can be gotten in the industrial world. This is undoubtedly necessary to complete the training.

A. H. Halloran. The gist of Professors Hillebrand and Charters' paper and also of the discussion thereon is well expressed in the following quotation:

"You can lead a horse to water,
But you can't make him drink;
You can send a boy to college,
But you can't make him think."

As intimated by this paper, the college is too heavily debited with the failure of technical men. It may be also added, is too heavily credited for their success. Colleges and college men are inclined to take themselves too seriously.

As a preliminary to a discussion of this subject it is first necessary to come to a common understanding as to what constitutes success—whether it means Success, or whether it is upon the higher plane of having made the world better by living in it. Most of you will agree however, that when a man's name becomes synonymous with his work, and his work synonymous with his name, he may be considered successful.

To attain this distinction he must know something about everything, and everything about something. This something about which he knows everything is his specialty. A college course affords a brief opportunity to learn a little of the first part of this requirement; but it takes many years after graduation before a man can complete the first, and get a good start on the second.

All that the college can hope to do is to provide him with the tools. A thorough grounding in mathematics, physics, chemistry and drawing will teach him to think clearly, give him the groundwork for more advanced study, and gain him an immediate livelihood if necessary. It is perhaps well to indicate in the last years of a college course the industrial significance of these elements, and give the man a start along some line which he prefers or for which he appears to have some aptitude. With this knowledge and ability he can work out the problems that will come up in practical work, and at the same time will not antagonize his co-workers by the assumption of a superior knowledge.

And last, and most important, a man must be taught how to speak and write correctly, for thereon rests much of his success in getting a position and winning promotion. The preparation of reports, specifications and contracts is one of the most important duties of a successful technical man. Their purpose fails if they are not clearly and concisely written, and there are today many lawyers who gain their livelihood from the mistakes of engineers. English is also the basis of that highest technical education, the study of the classics, which Steinmetz has urged. Finally, how is a man's name to be synonymous with his work in your mind and mine if we do not know the man, simply because he cannot write or talk about what he has done?

K. G. Dunn: This reminds me of a meeting that I attended about sixteen years ago, drawing up the standard specifications of an engineer. One party said that the engineer should be nine-tenths electrical engineer and one-tenth mechanical engineer to make a good electrical engineer. Another party said he would reverse the proportions. The best man would be the man whose education was nine-tenths mechanical and one-tenth electrical; and that struck me as rather funny, so I said the best man was the one who was one-tenth mechanical, one-tenth electrical, and the balance common sense, and if he was endowed with horse sense he would beat everyone of them. Horse sense or judgment is what counts.

On the salary proposition, it also reminds me, I was talking with a well known engineer, and I stated that the majority of people did not get paid in proportion to what they knew; it was more what they did. And he said that applied all right until a man reached the time of life when the people got acquainted with what he thought he knew.

C. L. Cory: I think your story about the examination in electrical engineering given by Professor D. C. Jackson, Mr. Chairman, might with propriety be supplemented by a statement from myself. To begin with, I will start in by saying that at the University of California, as probably some of you personally know, all the examinations in electrical engineering are so arranged that the students have all the books and other sources of information they desire available, and they are told it is perfectly proper for them to get information from any source except one another, and I am inclined to think that at California, as well as Wisconsin, the origin of that sort of an examination was about as follows:

One day in the summer of 1897 Professor Jackson and I were fishing on one of the beautiful lakes near Madison. We did not catch a fish, but we did a deal of talking, and I think that that day we both concluded that if we were called upon to do a piece of engineering work it would be rather hard on us unless we were allowed to do that which we had for a long time been doing, namely, have available all the sources of information which we could get, collect as many facts as possible, and then depend upon ourselves for the proper conclusions. This principle was impressed upon me more firmly not long after that, I think it was during the latter part of the same year. I was requested to make a complete report, stating the reasons why it was not good practice to use 500 volt grounded circuits for ordinary domestic electric lighting. In order to back up certain general propositions which I was ready to defend, it was quite necessary for me to look into the literature on the subject most carefully and obtain as many specific references to the subject as I could find. I worked a number of days on that report, and I think I had as many as fifty books open before me in trying to get together the important opinions and conclusions regarding this particular subject.

I am inclined to think that an examination at college should in a general way represent a piece of work that the student is called upon to do; quite the same as he will have to do when he gets out of the university. Such a piece of work does not necessarily call upon the memory to any degree. To attempt to collect information by memory is abominable. The work of the engineer which is worth while demands the ability to think, to seek out all information and to come to a conclusion after he has carefully collected all the information obtainable, and perhaps the kind of examinations that the men at the University of California get now, as well as the one you ran into as a student, Mr.

Lisberger, at Wisconsin, may have resulted from the fishing trip of Professor Jackson and myself.

W. A. Hillebrand: Mr. Chairman and gentlemen: I am from Missouri. You must show me that a man who is sitting in a class room with his mind principally on a game that is coming off I think two weeks from today, and wondering how big a score Stanford will pile up against California, or the reverse, is getting mental training.

Another point: Mr. Halloran said that a man who has had the preliminary training in mathematics has been trained to think. Now we get these men, get them fresh, and the one thing that stands out prominently above all things is that they are not trained to think; that they can't do it. Professor Ryan and I both agree, that there is really more discipline in a course of logic, or perhaps Latin, than pure mathematics. These make greater demands upon the resources of the student himself and will bring out more latent power than the teaching of mathematics as conducted today, which lays very large emphasis upon mechanical operations. I think it is perfectly legitimate to say that ninety per cent of my time is devoted to an effort to teach men to think.

The problem work in our department comes in in this way: In a course for instance in senior work, the class-room work and the laboratory are run along together. A man studying the characteristics of an alternator is working with it at the same time. By the time his report is finished and handed in, he has hammer him from the laboratory; you must hammer him from the it is a common experience for Mr. Charters and myself to find a man whose mind has not been wandering during the course but who has been paying attention is absolutely ignorant of facts that have been dwelt on in detail in the classroom.

This is not Mr. Van Norden's case—this sub-conscious matter coming in a flash uppermost in his mind; the information that the professor has unloaded upon him bursting upon his vision again. It is not waiting two years or five years, when there might have been an excuse for forgetting. It is a day, or a week, or two or three weeks afterwards, and he knows disconcertingly little about it. You have to give it over and over and over again. You must get at the man inside and out. You must had the benefit of the class work and the laboratory work. Now class-room, and above all in personal interviews when you are discussing your reports with him. A man does not have to be in the teaching business very long before he finds out how surprisingly little of what you try to impart to these people they are able to give back to you. We find it one of the most difficult things in the world to get hold of just what the man really knows, of just how much he has been able to get of what you have endeavored to impart to him. That very question of trying to teach them horse sense—the very question of teaching them to analyze a situation is absolutely the most difficult, the most nerve-racking that is put up to the teacher of engineering today. I have found the final examination to be most profitable along the lines suggested by Mr. Lisberger and Mr. Cory. In the particular examination that I give, I have certain preliminary examinations during the semester; and the man who makes a successful grade, or convinces me that he has done honest and faithful work, is allowed to take this final problem. He is turned loose on it for a week or ten days. He can get any text book; use any of his notes, or anything that he has got, but he is not to consult any other instructor or any of his fellows, but he may come to me. The idea is I want to know how much he has been able to do for himself.

Mr. Lisberger spoke of the young man who had wired bells around the house, and as a result of that wanted to become an electrical engineer. We had a striking example. A man had nearly finished his sophomore year, and during that time he had been put through the ordinary regime, and doubts began to arise in his mind, and he came to us. He figured it this way: He said, "It's all right, but this business of wiring bells don't amount to much. Otherwise I could not have done it. There must be more to this electrical engineering besides this;" and so after we talked the matter over with him he decided to change, and he is going into the hardware business with his father. This I consider a most unusual case—a man interested in his career and what he is going to do, and who really analyzed his own capabilities, his own tastes, and tries to figure out what he can do.

Now we come to the point upon which Mr. Cory laid particular stress, wherein he claimed that the university could do a good deal more than apparently we seem to think, in the way of giving a man discipline. The point of view of the student is admirably illustrated by what one teacher told me a little while ago. He said he was tired of this proposition of procrastination and delay in handing in the work on time; and he made a rule that reports were due on a certain date, and if it were not in on that day it was marked zero, no matter what the scholarship. There was a young man of average ability who protested that that worked a hardship on him. "Well," said the instructor, "suppose in a case at law, that the case came to trial at a certain day, and the report had to be there, what would you do?" "Well," he said, "that is something I would have to do."

It is that point of view that you have to combat. We have much the same requirements at Stanford. Work is due at a certain time. Otherwise it is not considered.

The average age of our entering freshmen is something over twenty years. Suppose you take a man who, throughout those twenty years, has never had to do any one thing with regularity; is it fair to expect the University to equip him with what his father and mother, during the twenty years or so that they had him more or less directly under their care, have not been able to give to him? It it to be expected that the university or individual instructors, who see him three or five times a week, will be able to give him that discipline?

There is a striking example in the case of the San Francisco earthquake. The Stanford students came here to help in the relief after the fire had been put out and things began to settle down. They were generally put on the task of making a house to house canvass to get information as to the number of residents in each house, as affording the Relief Committee a basis for the distribution of supplies. It was an irksome and disagreeable job. The men began to drop out of it one by one just as soon as the novelty was worn off, and soon the allurements of home and vacation and other things drew them away. The gentlemen who had charge of the Stanford Relief Corps said that the men who at last were giving their time to this work were the least able to afford it, men who were working to support themselves. His remarks in the case were significant. He said that these men had learned to stay by a job after it became disagreeable. For instance, if a man is waiting at table he must be there on time three times a day, seven days a week. He is getting disciplinary training. There are certain other men, cradled in the lap of luxury, to use a hackneyed expression, who are willing to submit to that discipline; they expect it, and when the time comes they are willing to submit to it; but I doubt very much if the university can do much for a man who has not already something of it in him, and who has not a point of view that will help him to submit to it when the time comes.

We had some twenty-five or thirty of our students who came up last February to help out on a test of the Great Western Power Company's plant in Oakland. It was rough work. There were six men reading meters, and the others were watching speeds and other things. The hours were long, and they did not like the food that was handed out to them. We heard about it for a long time afterwards. It was an eye-opener. Some of the men who had been doing the best work with us went down when they got up against the real thing. The other men who had had this discipline stayed by it, and were ready to go back again when the time came. There again you have it—the question of discipline—a discipline to your environment, which to our minds, in spite of what Mr. Cory has said, the university can impart only to a limited degree.

JOURNAL OF ELECTRICITY
POWER AND GAS

PUBLISHED WEEKLY BY THE

Technical Publishing Company

E. B. STRONG, President
A. H. HALLORAN, Vice President and Managing Editor
C. L. CORY, Secretary.

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604 MISSION STREET, SAN FRANCISCO

EASTERN OFFICE, 140 NASSAU STREET, NEW YORK
C. N. MANFRED, Eastern Manager

TERMS OF SUBSCRIPTION

United States, Cuba and Mexico	per year.	$2.50
Dominion of Canada	"	3.50
Other Foreign Countries within the Postal Union	"	5.00
Single Copies, Current Month	each	.10
Single Copies, prior to Current Month	"	.25

NOTICE TO ADVERTISERS

Changes of advertising copy should reach this office *ten days in advance of date of issue.* New advertisements will be accepted up to noon of Monday dated Saturday of the same week. Where proof is to be returned for approval, Eastern advertisers should mail copy at least thirty days in advance of date of issue.

Entered as second-class matter at the San Francisco Post Office as "The Electrical Journal," July 1895.
Entry changed to "The Journal of Electricity," September, 1895.
Entry changed to "The Journal of Electricity, Power and Gas." August 15, 1899.
Entry changed May 1, 1906, to "The Journal of Electricity, Power and Gas." Weekly.

FOUNDED 1887 AS THE
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Improving Centrifugal Pump Regulation

Though pumping water is one of the oldest uses to which power has been applied, it is still one of the most inefficient. The crude wheel by which the prehistoric Chaldeans irrigated their lands from the waters of the Tigris and Euphrates were but little more wasteful than the modern pump which seldom utilizes more than half of the energy delivered to its prime mover. The tremendous strides that have been made in improving the economy of the steam engine since Watt first used it for pumping water are yet to be duplicated in pumping equipment. The prototypes of both pump and steam engine were rotary machines, which, though long superseded by the reciprocating types, are now being adopted wherever weight of material, space occupied or economy of power are factors, as exemplified in the steam turbine and turbine pump.

The centrifugal is the form of turbine pump in most general use. Its name is derived from the fact that its action is largely due to the variation in pressure produced by the centrifugal force of a quantity of water rapidly rotated by the pump vanes. It is less than ten years since the centrifugal pump was recognized as simply a power turbine reversed, and though it is possible to design a turbine which will operate either as a motor or as a pump, just as dynamo electric machinery is reversible, the greatest efficiency is obtained only by a consideration of the special conditions in each case. Consequently German engineers have been perfecting theoretical designs and American engineers have been developing experimental models from either or both of which a practical pump may be produced with an efficiency approaching that of the turbine. One of the first fallacies that have been disproved by these investigations is the old idea that the centrifugal pump was adapted only to low heads, whereas compound or multi-stage pumps are now designed for almost any head and every service.

Aside from avoidable leaks of water and air, the chief losses in pumps are due to the water's frictional contact within the runner and to its directional changes without the runner. Friction occurs not only between water and castings but also between the eddying water particles. Changes in direction cause counter-currents and eddies whose impact nullify much of the power exerted. As these latter losses are the largest they have rightfully received the greatest attention and have been much reduced by designs providing proper entrance guidance and discharge diffusion. The energy of the discharged water is mostly kinetic and this must be converted into pressure energy for pumping purposes.

Such problems have occupied the attention of most investigators to the exclusion of the frictional losses within the runner. Consequently the exhaustive tests by Prof. Joseph N. Le Conte and his assistants at the University of California are a most notable and acceptable contribution to this subject. As a result of a long series of careful tests an empirical formula has been developed which gives the relation existing between the size and speed of circular pump impellers and the power required, as well as the effect of the size of the chamber in which these discs rotate.

PERSONALS.

Howard E. Pitts is now industrial engineer with the Pacific Gas and Electric Company.

R. G. Hanford of the United Light & Power Co. has returned to San Francisco from New York.

A. G. Wishon, general manager of the San Joaquin Light and Power Company, was at San Francisco from Fresno last week.

W. H. Holabird, who is interested in the Pacific Light and Power Company of Los Angeles, was a San Francisco visitor last week.

Edward L. Brayton, general manager of the Pelton Water Wheel Company, has returned from Southern California to his San Francisco office.

Archie Rice has resigned as head of the publicity department of the Pacific Gas and Electric Company because of serious trouble with his eyes.

George Henry, Jr., chief engineer of the Pelton Water Wheel Company, is in Oregon arranging the details of a new Pelton-Francis turbine installation.

H. W. Turner, president of the Montana Electric Company of Butte, is visiting San Francisco. He is also interested in an electric supply house at Spokane, Wash.

C. R. Ray, who is at the head of an electric light and power system having plants at Medford, Ore., and in Siskiyou County, Cal., spent last Friday at San Francisco.

James H. Wise, of the firm of F. G. Baum & Co., returned last week to his San Francisco office, after making an electrical engineering investigation in Northern California.

E. V. D. Johnson, general manager of the Northern California Power Company, has returned to Redding after spending some days in San Francisco under treatment for a fractured arm.

C. E. Sloan, of Spalding, Sloan & Robson, engineers, returned to San Francisco last Monday after quite a stay in Lassen County, where the firm is fulfilling a contract on an irrigation system.

F. C. Finkle, an electrical engineer of Los Angeles, who has been for years connected with some of the large electric power companies at Los Angeles, arrived at San Francisco during the past week.

R. S. Buck and Wynn Meredith, of Sanderson & Porter, are expected to return to the firm's San Francisco office about December 10th after spending some time in the Pacific Northwest and British Columbia.

Joseph J. Walsh, chief collector for the San Francisco Gas & Electric Co., was suddenly stricken with heart failure on November 19th, thus ending the career of one of the most popular and trusted employees of the company.

R. G. Dugdale, with the Fort Wayne Electric Works of Madison, Wis., and Herbert Duncan, connected with the company's San Francisco office, are making a tour of Northern California in the interests of the new electric rock drills.

J. A. Bumgarner, who is superintendent of construction for the Great Western Power Company, with headquarters at Oroville and jurisdiction from that point up to the hydroelectric plant at Big Bend, spent last Monday at the company's San Francisco office.

Frederick Stearns, of H. M. Byllesby & Co. of Chicago, is at San Francisco on business connected with the formation of Western States Gas & Electric Co., the new holding company just organized to take over the light and power plants now owned and to be acquired by the Byllesby interests in California.

Rudolph W. Van Norden, consulting civil and electrical engineer, has removed his offices to 517 Nevada Bank Building, San Francisco. The Nevada Bank Building was formerly the Union Trust Building, and is the same building in which Mr. Van Norden's offices on the third floor have heretofore been situated.

TRADE NOTE.

The General Electric Company has sold to the McCloud River Lumber Company one A.T.B. 400-kw., 1800-r.p.m., 2300-v., horizontal mixed-pressure, Curtis turbine generator set. It will be installed in the company's mill plant at McCloud. The turbine can be operated either way—at 125 lbs. high pressure, or on the exhaust at 16 lbs. absolute.

Cornelius Nestor, a representative of the Federal Storage Battery Car Company, a concern controlled by Edison and marketing his new storage battery, recently gave a demonstration of the battery at a meeting of the Geary-street Municipal Railway Association. An offer was made to operate a storage battery car on the Geary-street line for one month as a trial. A resolution was passed recommending the Mayor and Supervisors to accept the offer, as the association believes that this style of car is suited for the work.

NEW CATALOGUES.

Bulletin No. 140 from The Bristol Company, Waterbury, Conn., lists all regular lines of Bristol recording pressure and vacuum gauges.

The Engineering and Scientific Activities of the National Electric Lamp Association is the title of the recent bulletin from the Engineering Department of the Association.

Dearborn Drug and Chemical Works have issued an interesting booklet on the subject of Treatment of Boiler Feed Waters which shows their facilities for the special examination of each water sample submitted to them for treatment.

The Westinghouse Electric & Manufacturing Company, Pittsburg, Pa., has just issued section 3103 of its Perpetual Catalogue 3002-A on the subject of Motor Driven Elevators. The section contains a good many illustrations of typical installations.

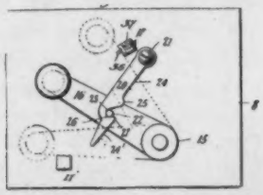
The Pacific States Electric Company of San Francisco, Los Angeles and Portland, announces that their new 1911 catalouge containing 1000 pages, will be ready for distribution early in December. It is of particular interest to central stations, isolated plants, dealers and constructing engineers and will be mailed free to the trade.

S. E. Doane's excellent paper on "High Efficiency Lamps and Their Effect in the Cost of Light to the Central Station" as read at the 1910 convention of the National Electric Light Association has been reprinted for general distribution by the Engineering Department of the National Electric Lamp Association together with several recent editorials in the leading electrical papers.

The Western Electric Company has just received from the press bulletin No. 1014, describing central battery, non-multiple telephone switchboards with magnetic signals. The switchboards presented in this bulletin are those recommended for central battery exchanges where the ultimate number of lines will not exceed 500. In this publication are described the advantages of the magnetic signal board over the lamp signal board. In this type of apparatus the line and cord circuit apparatus and wiring are of similar design and the amount of current consumed is slightly less than that consumed by the lamp signal board. The bulletin contains a description of the signals, jacks, circuits, and apparatus in this line of switchboards, going thoroughly into details. It is well illustrated with photographs, diagrams and tabulations.

PATENTS

976,422. Electric Switch. John Hastings Wooll, San Francisco, Cal. A motor starting switch having two positions, one the starting position and the other the running position, the movable switch parts being movable by gravity unrestrainedly downward from said starting position to said running position, a latch cooperating with said switch to hold

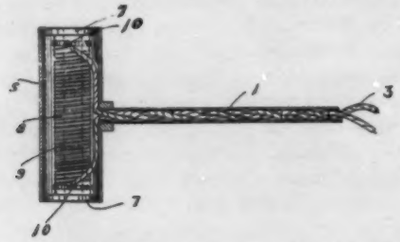


it normally in an intermediate position, but ineffective when the switch is allowed to fall from the starting to the running position, said switch being free from restraint when so moving, and lugs for limiting the movement of said switch parts, one of said lugs also serving to limit the movement of said latch.

976,404. Electrical Heater. Milton H. Shoenberg and George T. Marsh, San Francisco, Cal., assignors to Appliance and Electric Device Company. An electrical heating element consisting of a single conducting core of solid metal, a conducting resistance coil wound about said core, an insulating

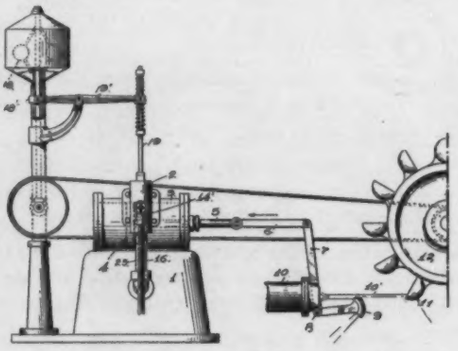
medium interposed between the core and coil, an insulation inclosing the coil, an exterior closed seamless tube flattened and compressed upon the outside of the exterior insulation. said resistance coil being connected at one end with the core and at the other end with an electrical terminal, said core having a connection with a similar terminal.

976,405. Electric Heater. Milton H. Shoenberg, San Francisco, Cal., assignor to The Presto Electrical Manufacturing Company. An electric heater comprising a casing open



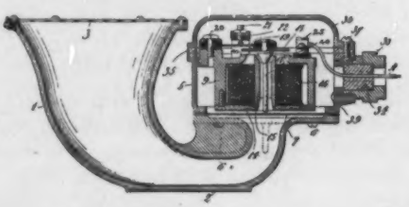
at both ends, a tubular handle secured thereto and extending at right angles therefrom, a tubular spool within said casing having both ends open and registering with the ends of the casing, the cavity between the spool and casing being closed at both ends, a high resistance wire upon said spool within said cavity, an insulating medium separating said wire from the spool, and conducting wires passing through said handle and connected to the resistance wire.

976,174. Standardizing Device for Governors. George J. Henry, Jr., San Francisco, Cal., assignor of one-half to The Pelton Water Wheel Company. The combination with a pressure cylinder, a fluid actuated piston working therein, for regulating the quantity of an impact stream issuing from a nozzle relative to a hydraulic motor, means thrown into action by the movement of the piston for varying the water



quantity of the impact stream relative to the driven motor to proportion the same to load variations, mechanism for supplying fluid under pressure to the pressure cylinder for moving the piston inwardly and outwardly, and means for reversing the flow of the fluid under pressure relative to the pressure cylinder to vary the movement of the piston working therein.

976,159. Electrically-Operated Signaling Horn. Egmont Max Tormin, Newton, Mass., assignor to Holtzer-Cabot Electric Company, Brookline, Mass. An electrically-operated signaling-horn comprising in combination a horn, a casing secured to the inner end thereof, a diaphragm interposed between said horn and casing, an electromagnet having a hollow



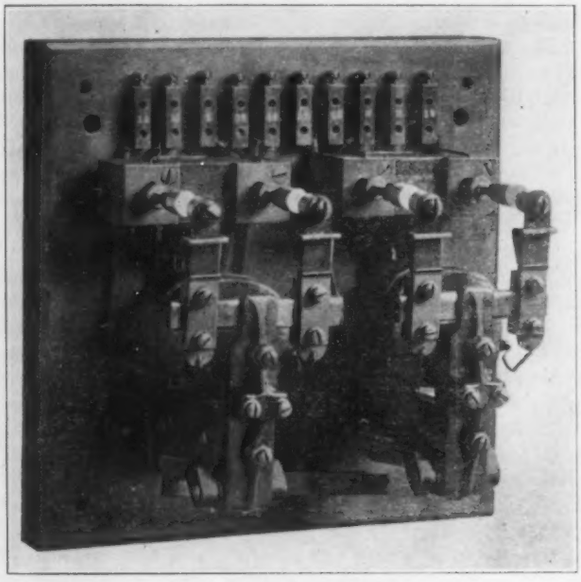
core, a plunger arranged within said core and having one end normally adjacent to, but not in contact with said diaphragm, a resilient supporting-member secured to the other end of said plunger, a circuit including the coil or said electro-magnet, means whereby said circuit may be automatically opened and closed, and means surrounding said hollow core and connected to said circuit for preventing sparking when said circuit is opened.

INDUSTRIAL

WESTINGHOUSE COMPANY BRINGS OUT NEW RELAY.

The Westinghouse Electric & Manufacturing Company has just brought out an entirely new design of the secondary or auxiliary relay for its induction regulators. The new relay is a radical departure from former types. It embodies several features that have been found desirable in this class of apparatus by the Westinghouse Company. These features insure excellent performance and long life.

The new relay is of the dry type, while the former was oil-immersed. The non-inductive resistance that was used in the old-style relay is used with the new style, but is now built as a primary part of the relay instead. This resistance, permanently connected across the contacts, absorbs the inductive discharge of the coils at the moment of breaking of contact, and assists in the elimination of sparking.



Relay for Voltage Regulator.

As all the wearing parts used in the new relay are case hardened it is very durable. In fact, the relay has been designed as a continually operating, hard service mechanism instead of as an instrument. The use of nickel for the relay contacts is a marked advancement, as it gives all the advantages of platinum, at a cost for renewals that is negligible. The result obtained from the operation of motor-operated regulators by means of this relay have been very satisfactory. The wear on the contacts is so slight that the adjustment and renewal of contacts is reduced to a minimum. When necessary, however, this adjustment or renewal can be very easily effected.

A feeder regulator will pay its cost in a short time by maintaining the voltage at a constant point. Close voltage regulation causes a decrease of lamp renewals, an increase in the sale of energy, an increased feeder capacity, and a higher economy of operation of the system; it helps greatly in making the customers satisfied with the illumination and service.

Central station managers now fully appreciate the economy to be effected by use of feeder regulators, and are rapidly taking them up. Formerly some mechanical troubles have been encountered in these, but, in their present state, Westinghouse regulators are practically as reliable as the static transformer.

A NEW TYPE RECTIFIER OUTFIT.

The mercury arc rectifier provides a convenient and efficient means of transforming alternating current to direct current and is meeting with a wide application in this field.

This device is used extensively to charge the batteries of electric automobiles, and the General Electric Company's universal battery charging rectifier outfit has met with great favor. It is complete with voltmeter, ammeter, and protective devices and is designed that it is suitable for a wide range of voltages and for current capacities ranging from 10 to 50 amperes.

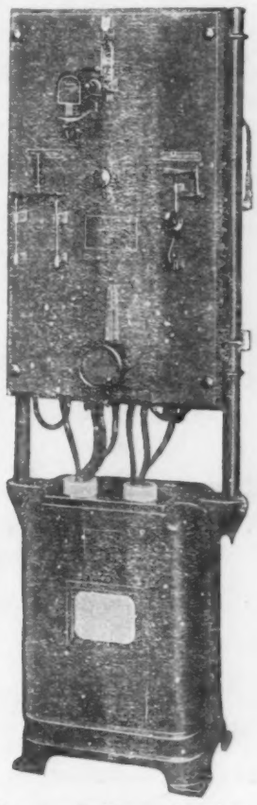


Fig. 1. Battery charging single phase mercury arc rectifier (front of panel).

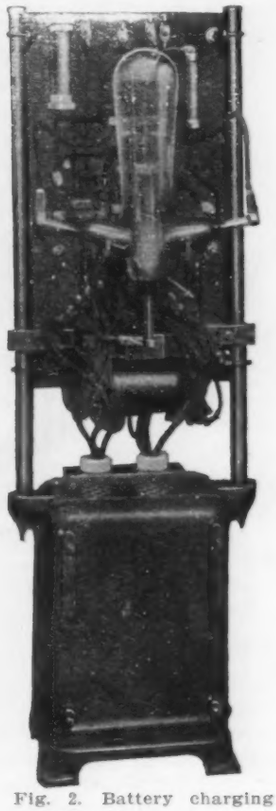


Fig. 2. Battery charging single phase mercury arc rectifier (back of panel).

To meet the demand for a less elaborate panel, the General Electric Company has recently placed on the market a rectifier designated as the "runabout type." This new rectifier is made up without voltmeter or ammeter. It is, therefore, recommended only for use with cars that are equipped with a first-class voltmeter and ammeter. It is designed to charge batteries consisting of from 20 to 32 cells at a maximum charging rate of 30 amperes.

The "runabout type" rectifier has one important advantage over the universal type—its extreme simplicity. As will be noted above, its range is limited to 20-32 cells, while the universal type will charge from 5-44 cells of lead plate battery. Therefore the former does not require special and elaborate means of adjusting current and voltages. It has only one small dial switch which gives a range of fine regulation sufficient for any battery from 20-32 cells. This means a simplicity not possessed by any other battery charging rectifier set and will make the set appeal to the many men and women who want to charge their own electrics but perhaps

hesitate to tackle the slightly more complicated appearing universal type.

Figs 1 and 2 show front and rear views of the new rectifier. This outfit is self supporting. The panel pipe supports are screwed into suitable receptacles on the compensating reactance which is of sufficient weight to hold up the rectifier panel and its equipment.

The outfit consists of four essential parts, rectifier tube, compensating reactance, regulating reactance and panel with supports.

The rectifier tube is an exhausted glass vessel that contains mercury. It has four electrical contacts (see wiring diagram "A," "A," the working anodes, "B" the cathode and "C" the starting anode.

The tube is mounted in a holder on the back of the panel. The shaft of the holder extends through the panel and is connected to a hand wheel on the front, by means of which the tube is tilted when starting the outfit. Fig. 2, which shows the back view of the rectifier panel, illustrates the form of the tube holder. Particular attention is called to its simplicity and to the evident ease with which a tube can be inserted.

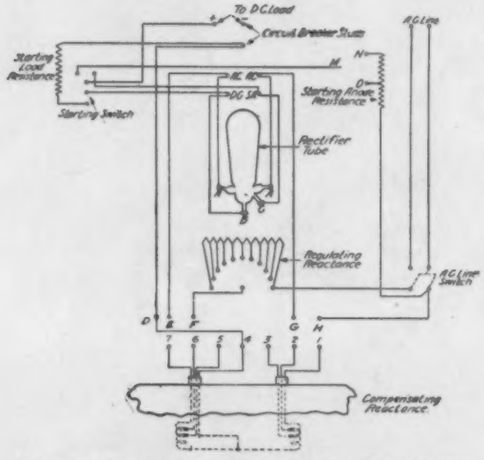


Fig. 3. Connections of single phase rectifier.

The function of the compensating reactance is to maintain the arc in the tube while the alternating current is passing through the zero point of the cycle. This reactance is so arranged that one lead is a negative pole of the rectified current while the other leads are arranged so that the reactance can be used as a compensator (thus its name, compensating reactance) so that by a few changes the outfit can be used on either 110 volts or 220 volts a. c. supply circuits and be able to charge a maximum of thirty-two cells.

Fine regulation of the direct current voltage is accomplished by means of a regulating reactance which is connected in the a. c. line. This reactance consists of a coil wound upon one leg of a rectangular laminated core. The coil has eleven taps, which are connected to studs on a dial switch mounted on the front of the rectifier panel.

The rectifier panel is of natural black slate 28 in. x 16 in. x 1½ in, and it is equipped with all switches necessary for the operation of the rectifier and the regulation of the charging current.

This simple, compact and inexpensive rectifier outfit will be found to be satisfactory in every respect for charging electric runabouts and other electric vehicles that have about the same number of cells and no doubt it will come into extended use in this connection.

ADAMS-BAGNALL ACQUIRES JANDUS.

Adams-Bagnall Electric Company of Cleveland, Ohio, has purchased the good will and assets of the Jandus Electric Company, Cleveland, Ohio. The Adams-Bagnall Electric Company will continue the manufacture of Jandus products and will exploit them under the trade name "Jandus," for example, Jandus fans, Jandus Luxolabra, etc. The Adams-Bagnall Electric Company has associated with it the former management of both the commercial and engineering department of the Jandus Electric Company. With the largely increased capital and extended facilities with which the business will in the future be conducted, the patrons of the Jandus Electric Company will find a greatly increased efficiency in meeting the demands of the trade.

RAILROADS OF NEW ENGLAND FAVOR TELEPHONE METHOD.

Railroads operating through New England have been among the leaders in the movement to replace the use of the telegraph with the telephone for the work of dispatching trains. The new method has been found satisfactory on a great many trunk lines of the country, and has many advantages in the way of accuracy, speed and safety.

The New York, New Haven and Hartford already has in operation telephone circuits covering 100 miles of its road from Northampton to New Haven, with branches to Holyoke and New Hartford. There are twenty-nine telephone stations on this division, which is equipped with test panels, selectors and flexiphones.

Sixty-eight stations are in operation on the Boston & Maine, covering the White Mountain division and the Concord division. These circuits extend from Concord to Woodside, 93 miles, White River Junction to Concord, 70 miles, and Boston to Fitchburg, 50 miles. The best grade of copper wire is being used, together with telephone arms, selectors, wrecking outfits and portable sets.

The Central Vermont has just ordered telephone equipment to cover its northern division from St. Albans to Windsor, Vermont. On this stretch of 150 miles there will be 38 telephone stations, which will be equipped with telephone arms and circular loom cable.

The Boston & Albany already has in successful operation telephone equipment covering the whole of its main line and all branches from Boston to Albany. On these four circuits, extending 390 miles, there are 165 stations.

The equipment of these railroads was furnished by the Western Electric Company, which has supplied more than 90 per cent of the railway telephone equipment now in use in this country. Other railroads are using the telephone for this service as far west as the Pacific coast and south as far as Florida and Texas.

WESTINGHOUSE HAND OPERATED UNIT SWITCH CONTROL.

The new Westinghouse hand operated unit switch control is attracting much interest and favorable comment among railway men. The company made this control an attractive feature in its exhibit at the Atlantic City Convention and has just issued a complete circular descriptive of the system. The trial Westinghouse HL equipment installed last April for the Fort Wayne & Wabash Valley Traction Company has proven so successful that an additional order for the same apparatus has now been placed and its satisfactory on this line has been a factor in several orders from the same vicinity.

A similar result followed the initial installation of this control on the Mahoning and Shenango Valley and Fairmont & Clarksburg lines, both companies ordering additional equipments after thoroughly testing the system in service. Recent orders placed with the Westinghouse Company for this HL control include equipments for the following roads: Ohio Electric Company, Illinois Traction Company, Peoria Railway & Terminal Company, Winona Interurban Railway Company, Indiana Union Traction Company, Alton, Jacksonville & Peoria Ry.

NEWS NOTES

INCORPORATIONS.

PAYETTE, IDAHO.—The Salmon Falls Light & Power Company, capital $100,000, has been incorporated by A. E. Wright, J. M. Swanson, W. C. Sturtevant, all of this place, to engage in general light and power business, to own and operate flour mills, sawmills and planing mills.

LOS ANGELES, CAL.—The Southern California Gas Company has been incorporated as a successor to the Domestic Gas Company and as a subsidiary of the Pacific Light and Power Corporation, by A. C. Johnston, Charles Foreman, E. R. Davis, A. N. Kemp and H. Baumgartner. A 10-inch high-pressure gas system is to be installed from Los Angeles to Pomona, with branch mains to all intermediate towns. From Pomona, where a distributing system is to be installed, a six-inch pipe line will run to San Bernardino, supplying other cities on the way. The plant at San Bernardino will be shut down and used only as an auxiliary station and smaller pressure lines will care for the country south and east of that point. Work on the San Bernardino construction will begin shortly after the first of the year.

FINANCIAL.

CENTRALIA, WASH.—Voters of this city will decide upon issuing $300,000 of bonds to pay for the system at a special election in November.

ASHLAND, CAL.—The City Council has approved and accepted the report of the Engineer, W. J. Roberts for the reconstruction of the municipal water plant and directed the recorder to proceed with the necessary steps to place the subject before the voters. The Council now has authority to issue $27,000 water works bonds and the bond election will be to authorize $143,000 more, making the sum of $170,000. The engineer's report estimates the cost at $160,103. It recommends two reservoirs of a combined capacity of 5,000,000 gallons of water.

SAN FRANCISCO, CAL.—At the annual meeting of the stockholders of the Northern California Power Company, held at San Francisco, November 23, President H. H. Noble made a favorable report as to the operations for the fiscal year ended Oct. 31, 1910: The following synopsis of the financial showing was included: 'The gross earnings of our corporation for the past year yere $578,082.37, which is a gain of $145,367.32 over that of the previous year. After paying all operating expenses and taxes our net earnings amounted to $406,834.39, which is an increase of $137,553.30 over the net earnings of the previous year. We have paid $210,000 in dividends and have added to our surplus $74,008.46 from the year's operations."

TRANSMISSION.

ONTARIO, CAL.—The stockholders of the San Antonio Water Company have decided to increase the power capacity of sub-station No. 1, the cost not to exceed $20,000.

WALLA WALLA, WASH.—W. B. Forshay, manager of the Pacific Light & Power Company, announces that the flooded power plant on the Walla Walla will not be abandoned. New electrical machinery will be installed.

BELLINGHAM, WASH.—City Engineer H. A. Whitney is advocating the proposition of the establishment of a $200,000 municipal electric power plant, and a flume. The plan can be carried out as soon as the city decides on the issuance of bonds.

REDMOND, ORE.—C. M. Redfield of the Deschutes Irrigation & Power Company, states that the receiver's sale has been approved by the court and that the reorganized company is ready to go ahead with construction work of the North canal.

NORTH YAKIMA, WASH.—Extension is to be undertaken at once by the Pacific Power & Light Company for taking its power lines through the Selah and Wenas valleys for the purpose of aiding ranchers who may desire electricity for irrigation purposes.

SPRINGFIELD, ORE.—The Northern Idaho & Montana Power Company has purchased from V. N. Sutton, a lot in Kelly's Addition to Springfield, the consideration being $100 per foot or $3300. The plan is to erect at Springfield a general sub-station and make this place a distributing point of power for the entire Willamette Valley. The company will at once commence the erection of a two-story brick building on the lot and it is to be ready for occupancy in February or March. The machinery alone to be installed will cost $150,000.

TRANSPORTATION.

MARTINEZ, CAL.—The first rail on the Oakland-Antioch electric railroad was laid last week at Bay Point, when workmen commenced the actual construction of the new line.

SPOKANE, WASH.—The Spokane, Portland & Northern Railway will start work on the construction of an electric line from this place to Davenport, Wash., about the first of the year.

OAKLAND, CAL.—The auditing and finance committee has reported that the application of the Oakland Traction Company for a franchise to operate a street railroad on Ninth avenue be granted.

LOS ANGELES, CAL.—Arrangements have been made by the Southern Pacific Railroad Co. to electrify its 170 miles of track between Los Angeles and Bakersfield. This transformation is to be completed by January 1, 1912.

FRESNO, CAL.—The project of S. N. Griffith for an interurban electric railroad between Fresno & Clovis took tangible form in an application made last week to the city trustees for a franchise to lay tracks within the city limits.

SAN RAFAEL, CAL.—A street railway franchise has been sold to George D. Shearer for $350. The franchise covers the principal streets in this city and stipulates that work on the road shall commence within three months and be completed within two years.

THE DALLES, ORE.—E. W. Thomas, who has a franchise for an electric railway system here, has started building operations. The road will reach all parts of the city and be extended into the country in every direction. Frank P. Phillips has the contract.

SALEM, ORE.—One of the important bills that will in all probability be brought up before the council for their consideration will be a bill for an ordinance granting to the Santiam Development Company a franchise over certain streets in this city. It is the purpose of the Santiam Development Company to construct an electric railway line between this city and Stayton and in the bill before the Council state that said line will be in operation within two years from the passage of the bill.

FRESNO, CAL.—The Fresno Traction Company is considering an extension of its lines to Mountain View cemetery by way of Forthcamp and Olive avenues. Superintendent F. W. Webster states that the line had been mapped out and the project approved. The matter now rests with the finance committee of the directors.

BELLINGHAM, WASH.—A $2,000,000 bond issue is back of the Nooksack Valley Traction Company, which plans to build a 60-mile road in Whatcom county. The bonds will pay 6 per cent interest and be for 30 years. Vice-president Morrison states that the first piece of road to be built will be between the Guide Meridian road or Meridian street and the junction of the Marietta road with the Great Northern. The contract will be let in a few weeks.

SAN FRANCISCO, CAL.—The Good Government League, has filed with the Board of Supervisors a long petition setting forth the alleged inadaquate service furnished by the United Railroads to the people of San Francisco, and calling on the Supervisors to enact an ordinance that will give relief by providing a seat for each passenger and other requested improvements. The allegation is made that persons desiring to live in San Francisco are driven to the other bay cities, "it being less inconvenient in these particulars than a residence in this city."

SAN FRANCISCO, CAL.—Judge Seawell has rendered a decision in the case of the people of the State against the Sutter Street Railway Company and the United Railroads an action to declare forfeited the franchise governing the use of the outside railroad tracks on lower market street between Sansome street and the Ferry building. Under the decision of Judge Seawell, which was on demurrers filed by the defendants, the main fight between the city and the railroad companies involved to gain possession of the tracks will be between the plaintiff and the Sutter Street Railway Company, the original holder of the franchise. The United Railroads will not figure as an active defendant.

ILLUMINATION.

RICHMOND, CAL.—The Council has adopted the ordinance granting the Great Western Power Company a franchise to operate a power and electric lighting system in the streets of the city by the erection of poles and the stringing of wires.

RICHMOND, CAL.—A modern electric-lighting system with all modern improvements is the next innovation planned for this city. Manager H. B. Kinney of the Richmond Light & Power Company announces that he has received instructions from headquarters for the complete reconstruction of the plant.

LEWISTON, IDAHO.—Announcement was made at the special session of the City Council by General Manager Philbrick of the Lewiston-Clarkston Improvement Company that a contract has been let to Chas. C. Moore & Co. of San Francisco and the General Electric Company for the installation of a new steam power electric plant in Clarkston to cost $100,000.

OAKLAND, CAL.—Negotiations are pending for the absorption by the Pacific Gas & Electric Company of the Suburban Light & Power Company. The announcement of the proposed deal follows closely upon the closing of the deal by which the Pacific company will hereafter distribute the output of the Great Western Power Company. The Suburban company's holdings are estimated to be worth in the neighborhood of $1,000,000 and the company supplies light and power to Haywards, San Leandro, Niles, Irvington, Newark, Elmhurst, San Lorenzo, Pleasanton and other Alameda county towns. John A. Britton of the Pacific Company admits that his company is planning to absorb the Suburban company, and says he expects the deal to be consummated before the first of the year.

BAKERSFIELD, CAL.—The Bakersfield Electric and Gas Company, which is a subsidiary company of the San Joaquin Light and Power Company, has signed a contract with the California Natural Gas Company for the supplying of the city of Bakersfield with natural gas. The gas well of the company is located in the Midway field, and pipe lines from it are already laid to within eight miles of the city of Bakersfield. It is expected that the connection will be completed within three weeks.

WATERWORKS.

TRACY, CAL.—Frederick C. Roberts, of San Francisco, has applied for a franchise to install a water system here.

PORTLAND, ORE.—Woodstock, Woodmere and Rose City Parks are preparing to ask the Water Board for larger water mains, which will insure enough water for fire protection.

OAKLAND, CAL.—It is believed that F. M. Smith is about to acquire a large holding in the Bay Cities Water Company. Mr. Smith was formerly heavily interested in the Peoples Water Company.

RED BLUFF, CAL.—Charles L. Crowder has filed an appropriation of 7000 inches of water in Deer creek to be used for the generation of power for commercial purposes. The point of diverting the water is about 15 miles southeast of Red Bluff.

WALLA WALLA, WASH.—Bids will be received by the city of Walla Walla at the water office up to 2 p. m., December 1 for furnishing six thousand feet of 20-inch waterpipe, more or less, f. o. b. Walla Walla. The bids are to be received on both iron and wood pipe. Iron details must be given, such as weight of pipe per foot, style of joints, etc.

FLAGSTAFF, ARIZ.—The city of Flagstaff and the Santa Fe Co. are about to agree over the ownership and use of Great Springs on the San Francisco mountains, from which Flagstaff is supplied with water. Attorney Capp of Los Angeles has proposed for the railroad company to surrender all claim upon the springs and to loan the municipality $92,000 necessary to build a storage reservoir and the money to draw 5 per cent, the city agreeing to sell 200,000 gallons daily to the company at a price that shall be mutually agreeable. It has been estimated that the springs have a flow of 700,000 gallons a day.

NORTH YAKIMA, WASH.—Geo. C. Arrowsmith of the Pacific Power & Light Company received orders from the head office of the company to proceed at once with the work of the extension of the present water main from the point where it enters the river, about 13 miles above the city to the reservoir at the end of the power canal, which is situated two miles further up the river and about 150 feet higher. The cost of the installation will be $32,000.

SAN JOSE, CAL.—A communication has been received from F. G. Volkers, City Plumbing Inspector, asking that the water company be required to extend its mains so as to supply water as follows: On Fourteenth street from Empire to the northerly city limits; on Eleventh street from Jackson to Taylor; on Vine street, from Grant to West Virginia; on Humboldt street from Mastick to Plum; on Mastick street from Humboldt to Floyd.

TELEPHONE AND TELEGRAPH.

SACRAMENTO, CAL.—The Home Telephone Company is to invade the Sacramento field. Plans are now being laid to get the business and install a plant. Representatives of the company have been here for several days and everything is ready for active work. The attorneys for the new company are now drawing up a franchise and the City Trustees will be asked at the next meeting to grant it.